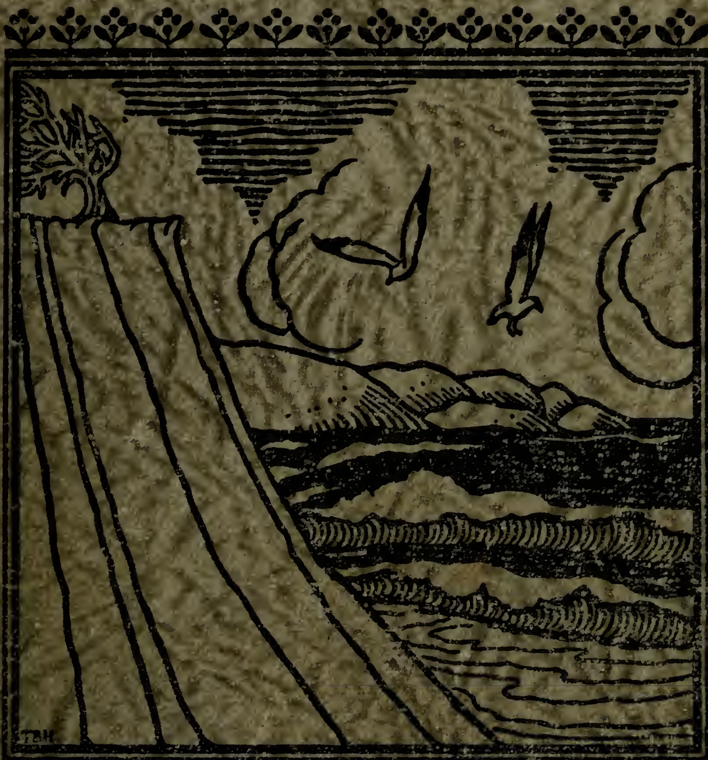
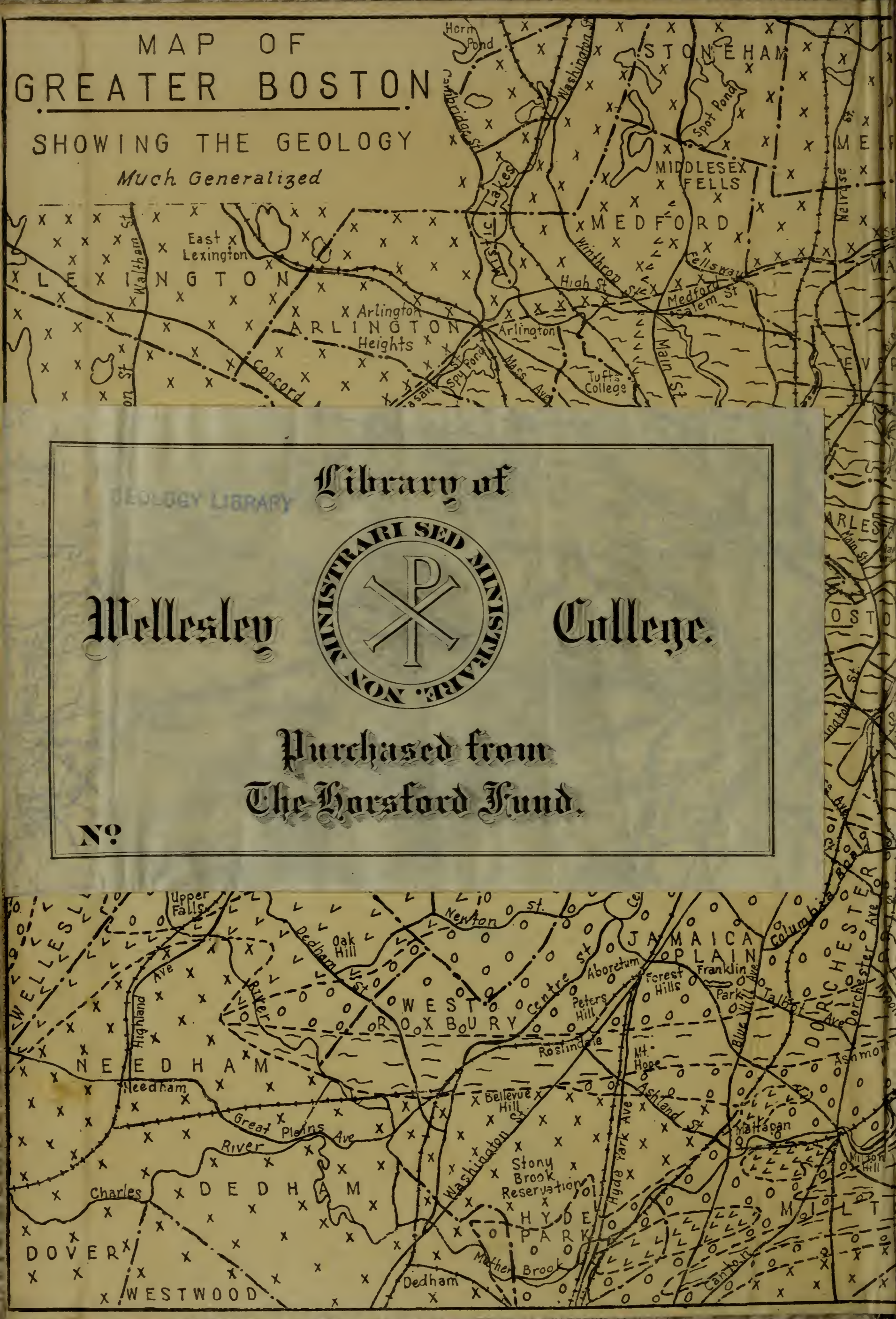


BOSTON
Through the Ages

IRVING B. CROSBY


MAP OF
GREATER BOSTON
SHOWING THE GEOLOGY
Much Generalized
STONEHAM
Spot Pond
MIDDLESEX FELLS
MEDFORD
Horn Pond
Washington St
Mystic Lakes
East Lexington
LEXINGTON
Waltham St
ARLINGTON
Arlington Heights
Arlington
Concord
Mass. Ave
Tufts College
High St
Winthrop St
Fellsway
Medford St
Salem St
Main St
Melrose St
Upper Falls
WELLESLEY
Oak Hill
Dedham St
Newton St
JAMAICA PLAIN
Arboretum
Forest Hills
Franklin Park
Centre St
Peters Hill
WEST ROXBURY
Columbia Road
Talbot Ave
Dorchester Ave
Blue Hill Ave
DORCHESTER
Highland Ave
River
NEEDHAM
Needham
Great Plains Ave
River
Charles
DEDHAM
Bellevue Hill
Washington St
Stony Brook Reservation
Roslindale
Mt. Hope
Ashland St
Hyde Park Ave
Mattapan
HYDE PARK
Milton Hill
MILTON
DOVER
WESTWOOD
Dedham
Mother Brook
Canton


SWAMPSCOT
SAUGUS
Main St
Broadway St
Lincoln Ave
Western Ave
Little Nahant
NAHANT
REVERE
Revere Beach
Broadway Revere
Beach
Boulevard
Beachmont
Orient Heights
Grovers Cliff
WINTHROP
Winthrop Beach
Great Head
Point Shirley
Deer I.
EAST BOSTON
BOSTON HARBOR
Governors I.
Castle I.
LEGEND
Scale of Miles
0 1/4 1/2 3/4 1 2 3 4
Town Boundaries
Boundaries of Geological Formations
Conglomerate
Slate
Lavas of the Boston Basin
Granite, Diorite, Felsite, & other Rocks outside the Basin
Calf I
Islands
Brewster
Boston Light
Hixes Mate
Lowell I.
Gallups I
Georges I.
Spectacle I.
Long Island
Thompson I.
Moon I.
Squantum
Telegraph Hill
Peddocks Island
Strawberry Hill
Nantasket Beach
Bumkin I.
Atlantic
Hancock St
Wollaston
Hough's Neck
Grape I
Slate I
East Milton
Forbes Hill
Adams St
Quincy Quarries
QUINCY
Weymouth Fore River
Weymouth Back River
WEYMOUTH
HINGHAM
Hingham

BOSTON THROUGH THE AGES

A Volcano in Action. Such as Once Existed in Boston.

BOSTON THROUGH THE AGES

THE GEOLOGICAL STORY OF GREATER BOSTON

BY

IRVING B. CROSBY

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TO THE MEMORY OF
MY FATHER

FOREWORD

It has long been recognized that a knowledge of the history of one's country is essential to an active appreciation of its stage of civilization. It is similarly true that a knowledge of the form of the land upon which we dwell and over which we pursue our avocations gives us a most desirable esthetic appreciation of it. Rock and sand and pond are not mere matter, but matter with an interesting and greatly extended pa[illegible]. The hills and valleys about us, the rocks and s[illegible]umps, islands and beaches, rivers and lakes, all h[illegible]ve their own fascinating stories.

It is such stories that Mr. Crosby h[illegible]oven into a series of chapters, written in a style [illegible]t [illegible] simple and truthful. His broad training, obtained at the Massachusetts Institute of Technology, Harvard and Columbia Universities, and through association in engineering problems with his father, W. O. Crosby, is seen in his choice of subjects and in their scientific treatment. Mr. Crosby has here given us what has long been needed, a small, readable, truthful book on the lands and shores of Boston and vicinity.

Hervey W. Shimer

Massachusetts Institute of Technology
June 20, 1927.

CONTENTS

LIST OF ILLUSTRATIONS AND MAPS

INTRODUCTION

Probably no large city has so much interesting geology and topography close at hand and available as has Boston. While leading geological walks for the Appalachian Mountain Club I have realized that many would like to have a better understanding of the land on which they live and which furnishes the background for every event of their daily lives, but it has not been easy for the uninitiated to find the information in a form that could be readily understood. Feeling that here was a lack which ought to be filled, I have attempted to present the geological story of Greater Boston in a simple form.

We all wish to observe and appreciate what is about us, but we do that more easily if we have learned to observe as children, and therefore this little book has been designed for use in the schools. It is hoped that it will stimulate interest in nature, give some information to school children and also be of value to older readers.

Those wishing to make a more detailed study of the geology of the Boston Basin will find a list of the more important articles on the subject in the Bibliography. In the section on Localities of Geological Interest, many places where geological features can be seen are described.

The geology of Boston has been studied for more than half a century but comparatively few have gone into it deeply. Among these was Professor W. O. Crosby, the writer's father, who devoted many years of his life to unravelling the local problems. His "Geology of the Boston Basin" covers the southern part of the area in great detail, but the work was never completed. This work, his other writings, and publications by other authors, have been consulted in preparing this book.

There are several points upon which the local geologists do not agree. In such cases the conclusions of Professor Crosby have been followed. Some details of the geological history have been intentionally omitted because they are not essential to the interpretation of the present land forms and it was desired to keep the book as simple as possible. Mention may be made here of the glacial period at the end of the Carboniferous Age. The conglomerate at Squantum has peculiar characteristics, is believed to be the consolidated boulder clay, or till, of that old glacial period and is called tillite.

It is impossible to estimate with great accuracy the age of geological events in years. The ages given here are according to Barrell.

The writer has been fortunate in having the kind advice and assistance of many persons. He wishes to express his gratitude to Professor Hervey W. Shimer of the Massachusetts Institute of Technology for

carefully going over the geological presentation to see that in the endeavor to make it understandable no deviation had been made from the facts, to Professor Alfred C. Lane of Tufts College, and Professor George H. Barton of the Teachers School of Science, both of whom have given valuable assistance in compiling the list of geological localities appearing in the later part of the volume. He is much indebted to the following for advice as to the method of presentation: Mr. Arthur L. Gould, Assistant Superintendent of the Boston Public Schools, Mr. Leonard O. Packard of the Teachers College of the city of Boston and Mr. Edson L. Ford of the Winship School; also to Dr. Oliver H. Howe of Cohasset for an old sketch of Winthrop Head, to H. A. Boss of Ludlow, Vermont, for the photograph of the work of the flood at Cavendish, Vermont, and to the *Boston Globe* for kindly allowing the use of material from a series of articles by the writer entitled "Boston Before Columbus."

BOSTON THROUGH THE AGES

BOSTON THROUGH THE AGES

READING THE DIM PAST

VOLCANOES! Earthquakes! Floods! Terrific upheavals completely changing the face of nature! Did you know that such awesome events had occurred where our busy city now stands? Our apparently stable land has been sunk under the sea and raised up again; it has been shaken by frightful earthquakes and blown open by volcanoes. Imagine a mountain spitting fire and pouring out floods of molten rock in West Roxbury! Had our city been here then it would have been destroyed under the lava and ash as happened to Pompeii and other cities.

How do we know these things? By studying the rocks and the processes of nature we learn what has happened in the past. This study is called geology.

After a man has lived in a house a long time he leaves many marks on it. A detective could study these and find out much about the man even though he had never seen him. Nature leaves her marks and signs in the rocks. The geologist is the detective who studies them and learns something of the earth's past history. Nature did not write in English or any other human language, but the writings of nature are just as plain as if they were written in English. The

geologist interprets the rocks and tells us about the past. He learns many things we can use in our daily life.

When we try to discover the secrets of the past it is like hunting for buried treasure. If we search hit or miss, without any plan, we may never find the treasure, but if we first obtain a clue and study out

Erosion of a Steep Slope
Showing the gullies or little valleys formed during rains

the secret code we can easily find it. Geologists have studied the code of nature and found that the present furnishes the key to the past.

To find out how a large valley was made long ago let us see how small valleys are being made now. After a heavy rain we can see little streams running down the hillsides and wearing out gullies or little valleys; the larger the stream the larger the valley becomes, the longer the stream flows the deeper

The Work of a River, Yellowstone Canyon

down it cuts. If we watch the work of the rain on a barren hillside of soft soil we can see great changes take place in a year. Deep gullies are formed with steep ridges between them, in fact we can see miniature mountain ranges with rugged canyons in the making. If we watched long enough we might see the hillside worn down to a plain. This wearing down is called erosion. It is going on during every rain, on all the hillsides and in all the streams year after year.

After we have watched our little stream for a short time and seen the gully it has made, let us imagine that it is a mighty river and has been flowing for a very long time, then our gully would have become a large valley. When we see a valley a mile deep we know that it took a long time for a river to carve it out. Most valleys are made by the rivers that flow in them. The ridges that are left between the valleys become hills and mountains. The busy streams make mountains as well as valleys.

Many examples of stream erosion can be seen in the parts of New England which were devastated by the great flood of November, 1927. Streams tore out new channels, in places a hundred feet deep, and changed the face of nature more in a few hours than they ordinarily would in many years. This emphasizes the fact that the great work of erosion is largely done in time of floods.

Water is soft and it does not seem as if it could ever wear away the rocks. It is true that pure water

Photograph by H. A. Boss

THE WORK OF THE FLOOD AT CAVENDISH, VERMONT
A Striking Demonstration of the Power of Running Water

On the night of November 3, 1927, the Black River overflowed through a gap in the hills, washed out a canyon some fifty feet deep and cut into the hillsides, leaving ragged bluffs over one hundred feet high. Seven houses with their barns and garages with the land they stood on disappeared in three hours, and the schoolhouse was left on the brink. The main street of the village was formerly where you now see the deep gully.

does not wear away hard rocks, but it picks up grains of sand and uses them as tools to do its work. If you rub your hand over a piece of hard wood you will not wear the wood, but if you put wet sand on your hand and rub the wood you will soon make a groove in it.

SQUANTUM HEAD
Showing a notch cut by the waves in a cliff of hard rock

This wearing, or erosion by running water, has been going on for many millions of years. It has caused great changes in the surface of the earth and has made most of our valleys and mountains.

If you carefully watch a stream you will see that where the swift current stops and the water becomes

quiet the sand which was being carried is dropped. You can see this in the gutters after a heavy rain.

Where the slope is steep the water will carry earth and sand, where the gutter is level the sand is dropped. This process of dropping is called deposition. Erosion and deposition are carried on by waves and wind as well as by streams. At Winthrop Head you can see where the waves are eroding the land. Part of the material eroded by the waves has been carried by the water and deposited on Winthrop Beach.

By studying the rocks we learn that the earth is many, many millions of years old, and that erosion and deposition have been going on all this time. Sand that was deposited long ago has been turned to rock. We have learned from the rocks that animals have lived on the earth for a very long time. When they died their bones or shells were sometimes covered by mud, the mud was changed into rock and the bones or shells were preserved. By studying these remains, which we call fossils, we can learn a great deal about the past. If we find fossils of seashells in a rock we know that the rock was formed in the sea. If we find these shells in rocks high up on a mountain we know that the shells were once in the sea, and that after they had been buried in the mud and become fossils, the rock was lifted up high above the sea. Then the rains fell and the streams ran and valleys

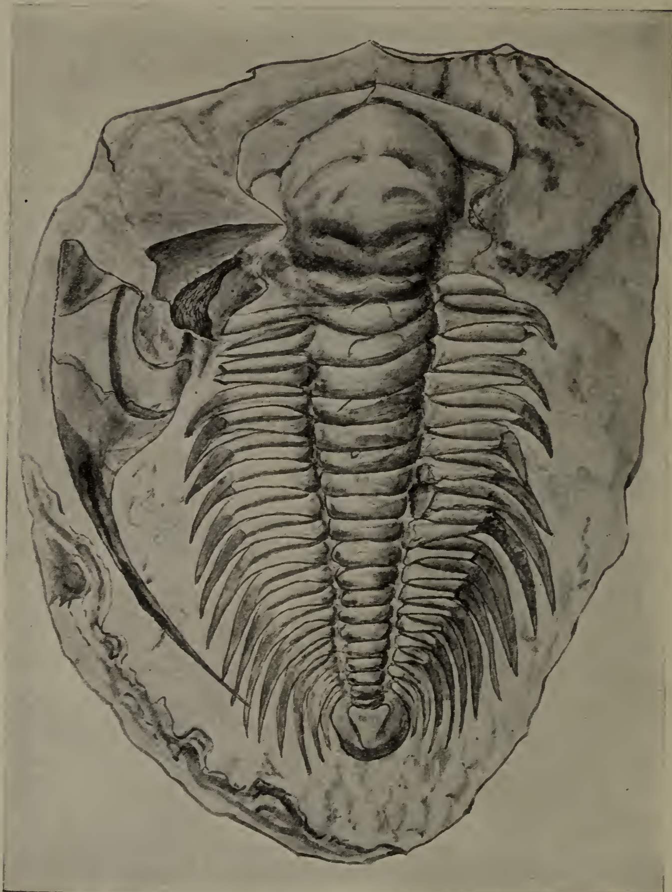
were carved out of the rocks, until finally mountains were left between the valleys.

Geologists have been studying the rocks and fossils for more than a century and have learned many things about the past. We know what the earth looked like millions of years ago and what kind of animals lived here.

QUINCY GRANITE

We were taught in school that the history of Boston began in 1630, but the history of the Boston region is hundreds of millions of years old. The oldest rocks near Boston are slates that were formed in the ocean probably half a billion years ago. Ledges of this rock, frequently called Braintree Slate, occur in North Weymouth, East Braintree and the southern parts of Quincy and Milton. Fossils have been found in the slate which tell us something about the life of that very distant time. There were then no land animals and no land plants, but queer creatures lived in the sea. One of these, called a Trilobite, was something like a lobster. It is millions of years since the last Trilobite lived, but by studying their fossils we know what they were like. It was their misfortune to have their stomach and brain in the same part of the body. Their voracious appetites caused the stomach to crowd the brain and made them slow and stupid creatures. Then the swifter fishes ate up their food, and finally the last of their race disappeared.

Long after the slate had been formed, strange things happened. The inside of the earth is known to be very hot. The deepest mines are occasionally so hot that it is difficult to work in them. At greater



From "Geology of the Boston Basin," by W. O. Crosby

A Fossil Trilobite, Natural Size
Showing the piece of rock in which it was found

depths the rock sometimes becomes liquid. It became liquid here and forced its way up into the slates, melting and pushing them aside. When this molten mass cooled, it formed granite and similar rocks, called igneous rocks because they were the product of great heat. Igneous rocks are composed of crystals of different minerals. One of the commonest kinds of this rock is granite, which consists of crystals of quartz, feldspar and mica or hornblende. A somewhat similar rock consisting of feldspar and hornblende is called diorite. This is darker than the granite. Granites and diorites were formed at this time. The diorite came first but the granite is much more important here. So much granite was made that little of the slate was left.

The formation of this granite was a very important event for Boston. It is the famous Quincy Granite of which so many buildings and monuments have been made. This Quincy Granite is coarse grained, showing that it was formed deep down in the earth and cooled very slowly. When an igneous rock flows out on the surface it cools quickly and forms a fine grained lava. If the lava is light colored it is called felsite, if it is dark it is called trap. Following the formation of the granite this region was land for a very long time, and was, therefore, subject to erosion. The rains fell and the streams flowed for millions of years, wearing away the surface until they had removed the rocks which were on top of the

granite, and now we can see large areas of it at the surface.

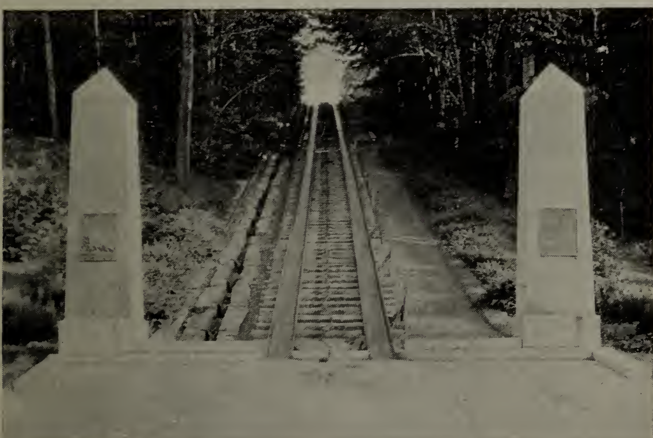
After the granite had been formed there were great strains in the rocks, which caused cracks. Some of these are vertical and some are horizontal; you can see them in the walls of the quarries; they are called

Photograph by H. I. Orne

A Quincy Granite Quarry
Showing joint cracks

joint cracks. Similar jointing also occurs in other rocks. The rocks break easily along these cracks, which helps the quarrymen in getting out large blocks of granite. In the big quarries at Quincy and West Quincy you can see them quarrying the granite by using wedges along the cracks and blasting with small amounts of powder. Thus large blocks are taken out without breaking. These are the most important quarries near Boston and they have been worked a long time.

The first railroad in this country was used to take granite from a quarry in West Quincy for building Bunker Hill Monument. It ran from the quarry to the Neponset River, where the rock was loaded on



Photograph by H. I. Orne

THE GRANITE RAILWAY AT WEST QUINCY
The first railroad in this country

boats and taken to Charlestown. Steam engines were not used on this road, but the cars were pulled by horses. The old Granite Railway was finally abandoned, but part of it has been taken over and used in the West Quincy branch of the New York, New Haven and Hartford Railroad. The quarry from which the granite for the monument was taken was on top of a hill, and the old railway descended the hill on a steep incline down which the cars were lowered by ropes. This incline is still in use but auto trucks now take the place of cars. The truck is let down by a steel cable which is controlled by an engine. At the bottom of the hill the cable is taken off, and the truck goes ahead under its own power.

Quincy Granite was used in many of the old buildings of Boston, but today the lighter colored stones obtainable in more distant quarries are preferred. Its principal use now is for monuments and tombstones, for which it is particularly well suited, as it takes a high polish and shows up its minerals beautifully.

ROXBURY PUDDINGSTONE

The first events of Boston history occurred about five hundred million years ago, as we have seen, when the Braintree Slates and later the Quincy Granites were formed. The next events in this history came after a very long time had elapsed, and we will resume our story half way down the ages from that time to this, long before man had appeared upon the earth. Then weird reptiles roamed the land, and in the dense forests were gigantic tree ferns and other strange plants which no longer exist.

When the Braintree Slates were laid down there were no animals or plants on the land, but by this time land animals and plants were numerous. If we could journey back through time to visit that weird land, there would be little that we could recognize. Our familiar hills and rivers did not exist. There were rivers and hills but they bore no resemblance to those we see today. Boston Harbor had not yet been made. Even the rocks were different. There was much granite but we would see no Roxbury Puddingstone. Strangest of all would be the animals and trees. Imagine great ferns as high as a house, and fierce reptiles, like huge crocodiles, living in Boston! We know about this life of the past, because men have studied the rocks and learned their secrets.

When the animals and plants died their bodies were sometimes buried in mud, which shut out the air and prevented decay. Gradually the mud hardened to stone and the hard parts of the bodies changed to stone. Thus the forms of the animals and plants were preserved as fossils, and geologists have dug them up and studied them in order that we may know what happened in that far distant time.

This region then consisted largely of granite and similar rocks. The earth became uneasy, this part of the country sank under the sea and Boston got its first salt water bath. A large bay was formed, about which were granite hills. From these hills swift streams flowed into the sea.

Perhaps you have heard how the Roxbury Puddingstone was made! Once upon a time, so the story goes, giants lived here, and at one of their great feasts they had a giant plum pudding, but instead of enjoying it they quarrelled and threw pieces of it at each other, scattering it over the country. The pudding turned to stone and you may see great masses of it now with its stony plums wherever the rocks show in Roxbury. Such is the fairy story, but truth is stranger than fiction, and the story that geology tells is more wonderful than the story of the giants.

There were hills along the shore and on these the rains fell and the winds blew just as they do now. The rocks were slowly rotted by the effects of the weather and broken up by the frost, forming gravel,

sand and clay. This breaking up of the rocks by the weather is called weathering. It is going on all the time, and you can see it wherever there is an excavation in rock. You will notice that the rock near the surface is often a different color and not so hard as the rock deeper down. This change is due to the fact that the surface rocks have been weathered but the deeper rocks have not.

This weathering went on for a very long time, and its products, sand, gravel and clay, were carried by streams to the sea. They used the sand and gravel to wear their channels deeper, thus breaking up more rock. This is all a part of the great process of erosion. First the rocks are broken up by weathering, then the products of weathering, called sediments, are carried by the streams which wear down their channels as they flow. Erosicn consists of weathering, wearing and carrying or transportation. Finally great quantities of sand and gravel were carried into the sea. The land continued to sink, and more and more gravel and sand were deposited on top of the first layers, until a great thickness of gravel and sand had been formed. The layers of sediments are called strata because they are stratified, that is, deposited in layers.

The clay that was carried in suspension by these streams was transported farther from the land, because it was finer, and was deposited in deep, quiet water where there were no currents. The land con-

tinued to sink and the water became deep where the gravel and sand had been dropped, and then clay was deposited over the gravel. This went on until a great thickness of clay had been laid down.

Photograph by H. I. Orne

A Conglomerate Ledge on Savin Hill, Near the John Lothrop Motley School

Showing the pebbles of which the rock is made

These deposits of gravel, sand and clay were hundreds of feet thick, and were so heavy that the pressure on the bottom layers hardened them to rock. More material was being added to the top,

increasing the pressure which caused more and more of the sediments to harden to rock. Natural cements were deposited in the sediments by ground waters, thus binding the gravel and sand and aiding in the process of making hard rock. The gravel changed into puddingstone, called conglomerate by geologists because it is a conglomeration of pebbles and sand cemented together. If you look carefully at the puddingstone you can see that it is made of pebbles, large and small. These pebbles are not all of the same kind of rock, but there are many pebbles of granite. The spaces between the pebbles were filled with sand. There is often a layer of sand in the conglomerate and that means that for a time, probably during a dry season when the streams were low, the currents were not so strong and could carry only sand.

The clay was hardened in a similar way and finally turned to slate. When clay is first hardened into rock it becomes shale, but after it has been under pressure for a long time it is hardened more and becomes slate. Rocks such as slate, sandstone and conglomerate, which are made from sediments, are called sedimentary rocks.

In Roxbury, West Roxbury and Dorchester most of the rock is conglomerate. One of the best places to see it is in Franklin Park where there are many ledges and boulders of it. Nearly all the rock in the Park is conglomerate and it shows especially well in

the ledges about the bear dens. There are also interesting ledges of it at Savin Hill and on the north

Photograph by H. I. Orne

A SLATE LEDGE AT SQUANTUM
Showing stratification

side of Parker Hill. Hundreds of other outcrops of this rock are scattered through these parts of the city. By looking at the geological map you can see where the conglomerate is, then it is easy to find a ledge which you can study and see how many different kinds of pebbles there are in it.

Drawn by Erwin J. Raisz

THE SOURCE OF OUR COAL. A SWAMP FOREST OF CARBONIFEROUS AGE

Lepidodendrons on the left, Sigillaria in the background, Calamites on the right and Tree Ferns in the middle ground. Amphibia, Myriapoda and giant dragon flies are shown.

The best place to see the slate is in Somerville, where it is found in numerous ledges. In the large quarry off Mystic Avenue you may study it to good advantage. Most of the rock in Somerville is slate, though there are many trap dikes. These are so small that they are not shown on the map. There is slate under Cambridge, Boston and South Boston, but it is buried so deeply that you can not see it unless you go down into a very deep excavation. Slate ledges are also found in the southern part of Dorchester and at Squantum.

What was going on in other parts of the country while the sea covered Boston and the conglomerate and slate were being laid down? In many places, and especially in Pennsylvania, the land was low and there were immense swamps with dense forests of strange trees and plants. As these died and fell into the swamps a great thickness of vegetable matter gradually accumulated. This was covered with mud and water which kept it from decaying and it slowly changed into coal. There is much carbon in wood and in other vegetable matter and coal is mostly carbon. At first peat was formed, then this changed into soft coal and when there was much heat the change continued until hard coal resulted. In some places where the heat and pressure were very great the coal was partly changed to graphite.

In western Pennsylvania, Ohio and other regions, soft coal was made; in eastern Pennsylvania the

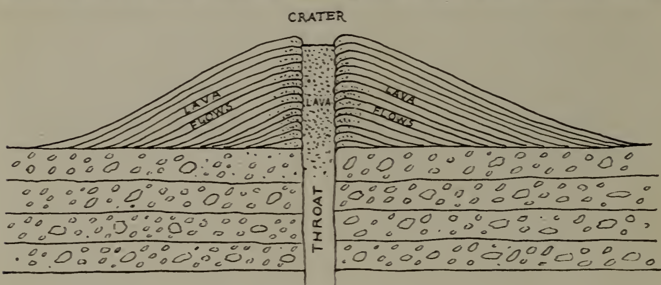
process went on until hard coal was the result. No coal was formed near Boston because this region was under the sea, but in southern Massachusetts and Rhode Island swamp forests existed and coal was formed. However this coal was so greatly changed by heat and pressure that it became graphite and is difficult to use, therefore it has not been, as yet, a commercial success. The hard coal that we use in Boston comes from eastern Pennsylvania, and the soft coal so much used in our factories comes from western Pennsylvania and the adjacent states. All the coal in the eastern United States was formed at this time and therefore this is called the Carboniferous Period. The conglomerate and slate of Boston were made during the Carboniferous Period.

Meanwhile trouble was brewing in the basement, and the country was being blown open by volcanoes and buried under floods of lava.

A VOLCANO IN WEST ROXBURY

While the conglomerate was being deposited the molten rock deep in the earth was getting uneasy, and liquid rock burst out on the surface forming volcanoes. One of these was in West Roxbury near the corner of Washington and Grove Streets.

When the liquid rock, or lava, poured out on the surface it flowed away in all directions and soon cooled and hardened into solid rock. More lava poured out over the first layers, this also cooled and



Cross Section of a Volcano
Showing the cone built up of layers of lava

hardened and gradually a cone was built up about the hole from which the lava came. In this way volcanic mountains are formed. If the lava was thin and flowed readily it built up a low cone, but if it was thick and sticky a steep sided cone was formed.

There are many volcanoes in the world. Some of

A Volcanic Cone and Lava Flow

them are active and some have been dead for a long time. Mount Vesuvius and Mount Etna in Italy are well known active volcanoes which occasionally erupt and pour out lava. The only active volcano in the United States is Lassen Peak in California, which erupted a few years ago. There are, however, a great many dead volcanoes in this country, and in the northwest are hundreds of thousands of square miles of lava.

Those of you who live in West Roxbury need not feel uneasy about the volcano which was formerly active there. It has been dead for more than a hundred million years and the cone has been entirely worn away. Now the district where the old volcano existed, near the corner of Washington and Grove Streets, is covered with streets and houses and it is difficult to realize that there was once a volcanic mountain there. If that volcano were active today it would not be safe to live in Boston, for great floods of red hot lava would pour out frequently, burning everything in its course. How do we know that there was once a volcano in West Roxbury? Because geologists have found a peculiar kind of rock there which they know was formed in the throat of a dying volcano by the cooling of the lava before it reached the surface.

The lava poured out on the bottom of the sea and layers of volcanic rock are found between the layers of conglomerate. When the lava became too stiff

to flow, it was blown out in pieces which fell in great quantities and formed thick layers. These have hardened into a rock which is called volcanic tuff. In Atlantic Hill at the south end of Nantasket Beach alternating layers of conglomerate, volcanic tuff and lava can be seen. There are six layers of conglomerate and six layers of lava and tuff. Black Rock, a quarter mile off shore from Green Hill, consists of lava, and it is believed that the volcano from which the lava and tuff came was near this place.

Volcanic rocks may also be seen at the Allston Playground in Brighton and in Mattapan near where Blue Hill Avenue crosses the railroad. These rocks are very fine grained, very hard and different from either the conglomerate, which contains pebbles, or the slate which is soft. Volcanic lavas are fine grained because they flowed out on the surface and cooled quickly before large crystals could form. The very dark colored volcanic rocks are called trap and the light colored are called felsite. Most of the lavas poured out in the Boston Basin made a rock intermediate in color between trap and felsite, known as melaphyre. Trap is a good rock for road-building and it is unfortunate that there is not more of it about Boston.

For long ages the formation of conglomerate, slate and lava continued until great thicknesses had accumulated and the Boston Basin was partly filled up. While these events were taking place the foun-

dations were getting weak. The increasing load of conglomerate, slate and lava finally caused a great block of the earth's crust to settle down. Great cracks, called faults, formed in the rocks and the huge mass between them sank. This did not occur all at once but the area between the faults sank a little at a time, accompanied by terrific earthquakes.

One of these faults is at the base of the highlands north of Boston, along a line at the foot of Arlington

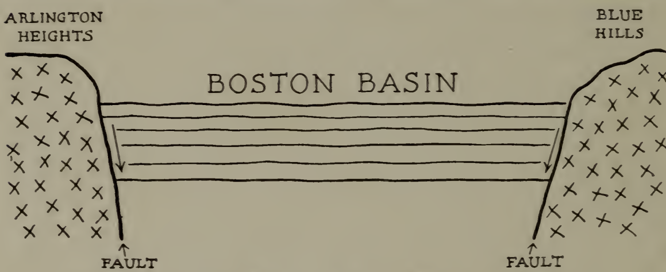


Diagram Showing How the Boston Basin was Formed

Heights, Prospect Hill and Middlesex Fells. Following this line a great crack formed in the rocks and the land south of the crack sank, while the land on the north side rose. The other great fault is along the north side of the Blue Hills. The sunken area between these faults is known geologically as the Boston Basin, because it forms a basin with higher land north and south.

If we stand at the summit of Arlington Heights, or Prospect Hill, or on a high point in the southern part of Middlesex Fells and look southward we can

see a broad lowland extending to the Blue Hills, about fourteen miles away. Then we can understand why this is called the Boston Basin. A similar view can be obtained by looking northward from the summit of Great Blue Hill or from several other points in the Blue Hills. From some of the elevations in the Boston Basin we can see the higher land north and south and get the impression of being in a basin.

The floor of the Boston Basin is not flat but is dotted with numerous hills. Most of these consist of clay and gravel, not solid rock, and were formed during the ice age many millions of years later.

The formation of the Boston Basin was accompanied by numerous earthquakes. Most earthquakes are the result of faulting. When strains accumulate in the rocks for a long time they are apt to break. The rock on one side of the crack moves, sometimes many feet. This movement causes great jarring which may shake the whole earth. After the San Francisco earthquake one could see that the earth on one side of the crack had been moved. In some cases roads and fences were cut across by the fault-crack and the fence on one edge of the crack moved sideways as much as sixteen feet from the fence on the other edge. In other cases the movement was vertical and cliffs several feet high were formed across roads.

Imagine the effect of dropping a block of the earth's crust a dozen miles square and thousands of

feet thick! The shaking and jarring would be terrific, but that is what happens in great earthquakes and what happened many times, when the bottom of the Boston Basin was sinking. The sinking went on slowly, little by little, for a long time until the Basin had gone down hundreds of feet. Every time it sank there were earthquakes. Fortunately there were no people here to suffer from the violent shocks.

We have no cause to worry about earthquakes occurring now on account of these faults. They have been quiet for millions of years and are firmly cemented, so that they are as strong as the surrounding rocks. The modern earthquakes which have been felt in Boston came from other faults not so near the city and these will be described later.

IN THE VISE

Mother Earth continued in a restless mood and the granitic rocks north and south of the Boston Basin pressed against the conglomerate, slate and lava in the basin and squeezed them as if they were in a gigantic vise.

If you push on the opposite edges of a piece of paper it will bend and fold. The rocks bent and folded under great pressure. They arched up in some places and bent down in others, forming great waves in the layers of rock. The most important arch was in Roxbury where the conglomerate was bent up by the folding. There were other arches in Brighton, southern Dorchester and Milton, but these were not so large. These upward curves of the layers, or strata, of rock are called anticlines. The arch or anticline in Brighton was folded very tightly and overturned, causing the rocks to break and become much confused. The downward curves of the folded rocks are called synclines. In Somerville and Cambridge the rocks were bent down and the conglomerate was folded deep into the earth and does not show at the surface.

It may seem strange to think of rocks as bending, but if a great pressure is applied for a long time the strongest rocks will bend. Some of the concrete

benches in our parks and subway stations have sagged until they have a noticeable bend. If the pressure is too great the rock will finally break.

The slate was folded with the conglomerate, and when it was squeezed extremely fine cracks were formed. These cracks in the slate are called cleavage and they cause the slate to split into thin layers. These thin layers of slate can be used for roofing, making the rock valuable. The slate in Somerville does not have the fine cleavage of many other slates.

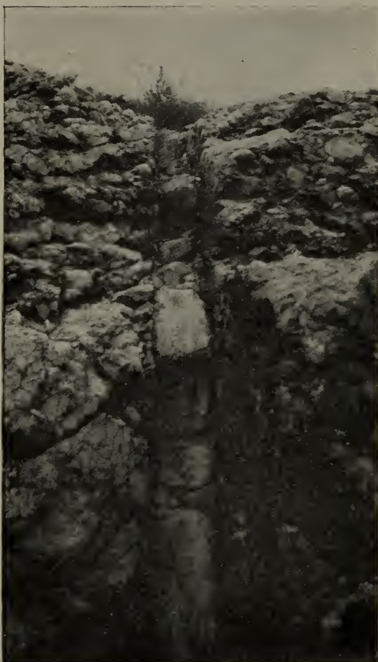
During the folding the rocks not only were cracked, but many faults were made. Molten rock rose up from deep down in the earth and filled the cracks. This slowly cooled and formed a fine-grained, dark-colored rock, called trap, which is different from the surrounding rocks.

The thin sheets of rock, usually trap, which fill the cracks in the older formations are called dikes. They vary from a few inches to several feet in width and may be found much wider. The dike is commonly finer grained and darker than the surrounding rocks, which makes it easy to recognize. When you see a band of fine-grained, dark-colored rock cutting through another rock it is probably a dike, and you know that it was once molten and flowed into cracks in the surrounding formations. We may not always know the exact age of the dike but we are certain that it is younger than the enclosing rocks.

There are a great many dikes about Boston and

An Anticline Showing Arched Strata of Slate

they are not hard to find. One of the best places to see them is along the rocky shore just south of Nantasket, at the foot of the hill where the Atlantic House formerly stood. They also show up well on the shore in Beach Bluff and Clifton between Swampscott and Marblehead. There are numerous dikes in Somerville and some of them may be seen in the quarry near Mystic Avenue and Temple Street. In Brighton, the Allston Playground near the corner of Warren Street and Commonwealth Avenue is a good place to see them. They are not common in Franklin Park, but may be seen in the walls of the old quarry.



A Dike on Wachusett Street
Opposite the Francis Parkman School at Forest Hills

When we see dikes it is interesting to understand what they mean. If we realize that molten rock filled cracks which were formed during the folding and

faulting of the formations they have a meaning for us.

After the rocks were folded and the dikes were formed, this region was raised high above the ocean and the surface was subjected to weathering. Frost got into the cracks and split the rocks, just as it will crack open a bottle or an automobile radiator. The rain and the streams wore the rocks away. You have learned that the action of frost, rain, streams and wind is called erosion and this is going on all the time.

For millions of years erosion worked on the surface of the Boston Basin and wore it down. The granite and similar igneous rocks were harder than the slate and conglomerate, and the latter wore away faster, leaving highlands of hard rock to the north and south rising above the Basin. Of the hills that rise above the floor of the Basin, those made of conglomerate stand the highest, since this resists erosion better than slate. There are rocky hills in Roxbury and West Roxbury, but none in Cambridge, because there soft slate predominates, while in the first two places conglomerate abounds.

When the rocks of the Basin were folded the tops of the arches, or anticlines, were lifted up high. Erosion works faster on the hills than in the valleys because there the streams are swifter. The crests of the anticlines which were made of slate were worn off. Finally all the slate was removed from the tops of these arches and the conglomerate was exposed. The four anticlines are in Brighton, Roxbury, the

southern part of Dorchester and Milton, and in these the rock is conglomerate or lava. The slate has been worn off from these places. In all four of the anticlines the flows of melaphyre in the conglomerate may be seen, and in the Dorchester and Milton anticlines erosion has cut through the conglomerate and melaphyre, exposing the felsite floor of the Boston Basin on which these were laid down. The largest syncline is in Cambridge and Somerville and here the slate still exists since it was more protected from erosion than on the tops of the anticlines, while the conglomerate is buried deep beneath it.

The Blue Hills remained high because their rocks were harder and did not wear away as fast as the rocks about them. The same is true of Prospect Hill, Arlington Heights and the Middlesex Fells. The Boston Basin was formed by the dropping down of a great block of the earth's crust. It was filled with deposits of gravel and clay which hardened into conglomerate and slate. These were worn down faster than the surrounding rocks, thus keeping the form of a basin. The Boston Basin was now in existence with hills of hard rock north and south of it, but this region still looked very different from its present aspect.

WHEN THE MERRIMAC CROSSED WASHINGTON STREET

The formation of the Boston Basin, about which we have already learned, was the first step in a series of events which were preparing the way for the site of a future city. North and south of the Basin were highlands of hard rocks. Between these was the Basin, a lowland where the rocks were softer.

Again for millions of years the rains fell, the streams flowed and the land was gradually worn down. No more volcanoes or great earthquakes changed the face of the country, but the slow process of erosion was carving the land into its present form, and toward the close of this long period the country looked somewhat as it does today. The Blue Hills rose above the surrounding region much as they do now. Prospect Hill, Arlington Heights, the Middlesex Fells and other hills north of Boston were somewhat the same as at present. It is true that they were higher than they are now and their shapes were not just the same, but there was a resemblance to the present forms. Between these highlands and enclosed by them lay the Boston Basin, but lacking most of the hills which now rise from its floor. The framework of the topography was now complete, but when we consider the details, there was little that is

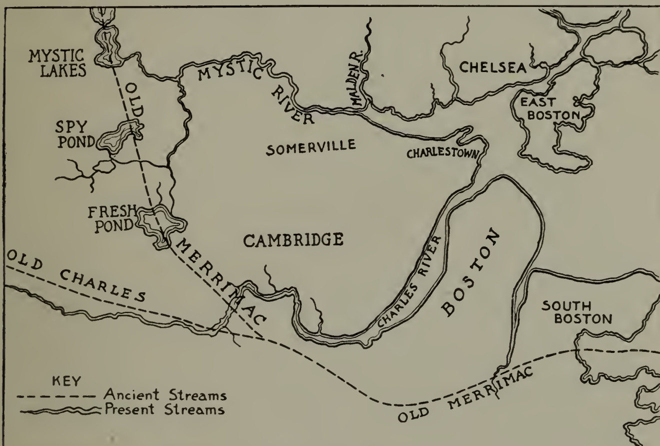
similar to modern conditions. Boston Harbor did not exist and the ocean was probably far away. Our numerous ponds were absent and the river systems were not recognizable.

Let us get into a magic airplane and travel back through time for more than a million years to see what this region looked like then. This is a very wonderful airplane and there is room for all of you. Now we are off. Of course there was no city in existence then and none of the works of man which are such important landmarks now. For convenience in locating ourselves we will speak of different parts of the city as though they existed. We are flying swiftly back through time at the rate of a million years a minute. Now we have gone back through the years to the period we wish to examine, so we will stop our backward flight and look about.

There are the Blue Hills! Prospect Hill and Arlington Heights are seen, but where is the harbor? There is no ocean nearby as today. Where are Jamaica Pond, Spy Pond, Fresh Pond and all the other ponds with which we are now familiar? They are all absent. We can not find some of the hills in the Basin. Corey Hill, Parker Hill, Beacon Hill and many others are not to be seen.

We must fly very low so that we can see what animals and plants lived here a million years ago. The plants and trees are not very different from the modern forms. Many of our familiar animals are

here also, but there are others which do not live in our modern times. There are mastodons and elephants. Today elephants are found only in tropical countries and no mastodons are living, but a million years ago these huge creatures roamed about Boston and we can see them from our magic airplane.



Map of the Old and Modern Rivers

Now let us look for our familiar rivers, the Mystic, Charles and Neponset. We search in vain; there are no streams which we can recognize. What is that great river flowing from the north? It comes out of the valley where our Mystic Lakes are now and flows through the Cambridge of today, across the present valley of the Charles. As we follow it seaward we shall find that it crosses Allston, the Back Bay and South End, and runs south of South

Boston out into a large valley where, at a later time, the harbor was to be. Far to the east, many miles away, we can dimly see the ocean with this large river flowing into it. Old Boston looks entirely different. Where we expect to find Boston Neck, along which Washington Street was built from Old Boston to Roxbury, we find instead a valley, two hundred feet deep, with this great river flowing through it.

Let us fly northward up this old river and see where it comes from. As we proceed in our magic airplane which annihilates both time and space, we see this river stretching north from Winchester, where we do not expect to find any river. Northward we go until we come to the location of Lowell. Here our old river coincides with the course of the modern Merrimac, but we see no river flowing from Lowell by Lawrence and Haverhill to the sea at Newburyport, as the modern Merrimac does. Now we will speed up our magic airplane and catch up with the present time, so that we can think it over and understand what we have observed.

A million years ago the Merrimac did not turn eastward at Lowell and flow into the sea at Newburyport, but instead it continued south from Lowell, by Winchester, and through Cambridge and Boston as we have seen. It was a large river and flowed in a deep valley. The Charles joined the Merrimac at Allston, but it was a different Charles, without falls, and not so crooked as the present river. There was

a river somewhat similar to the Neponset, but without the rapids at Mattapan and Milton Lower Mills. The Mystic did not exist at all, but the Merrimac flowed where the upper part of the Mystic now is. We see that, though the main features of the topog-

Mystic Lake in a Kettle Hole in the Valley of the Pre-Glacial Merrimac

raphy were like the modern ones, the rivers and ponds were entirely different.

You may say that this is all a pretty flight of the imagination, but can we prove it? Man has drilled many wells, some for water and some to get information for the foundation of buildings. In making these wells notes have been taken as to the depth to solid rock, and the nature of the material over the rock. Thousands of these records have been collected and

carefully studied by geologists. They find that under the Back Bay it is two hundred feet to solid rock. A buried valley can be traced eastward under the South End into the Old Harbor or Dorchester Bay. Northward this buried valley extends under Cambridge and Winchester to Lowell. By studying these well records, we know what the country looked like before the present soil was deposited on the rocks.

We have now traced the history of Boston up to a million years ago, and have seen that this district was shaken by earthquakes, drowned under the sea and covered by molten lava from volcanoes. But an even more amazing experience was in store for it.

THE ICE AGE

After the Boston Basin was formed and there had been a very long period of erosion, there was an uplift of the land. This was accompanied by a colder climate and an increased snowfall. More snow fell each winter than melted in the summer, so that it covered the ground the year around and became thicker and thicker each year. This accumulation of snow continued for a long time throughout the northern United States and Canada. As its thickness increased, it was compressed into ice by its own weight and by alternate thawing and freezing. In the winter you can see how the snow at the sides of the streets changes into ice.

The continued piling up of snow formed a great ice sheet or continental glacier. Such ice sheets cover Greenland and the Antarctic Continent today. Other parts of the world are cold enough to have an ice sheet, but there so little snow falls that it does not accumulate. The coldest place in the world is in east central Siberia, not at the north pole. There is no ice sheet in Siberia, because there is not sufficient snow. In some high mountains it is very cold and much snow falls, causing small ice sheets or mountain glaciers to be formed. Glaciers exist in the Rocky Mountains, the Alps and other high moun-

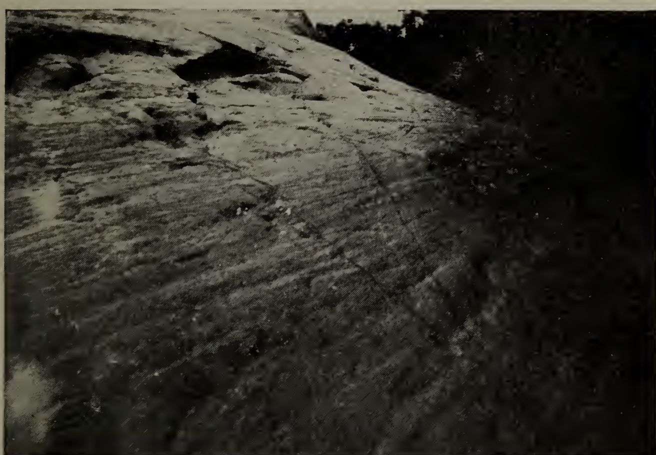
tains. The White Mountains of New Hampshire have no glaciers now, because the climate is not quite cold enough. A few thousand years ago there were glaciers in the White Mountains, and if a little more snow fell there each winter we would soon have glaciers started again.

A Mountain Glacier

The center of the great ice sheet which covered New England was in northern Quebec and Labrador. The accumulation of snow and of ice continued until it was two miles or more thick at the center. The pressure of the great thickness of ice caused it to move out very slowly from the center. If you spill some molasses on the table it spreads out slowly and in a similar way the ice spreads out at a slow rate. It took thousands of years for the great ice

sheet to form. It lasted many thousands of years and then slowly melted away.

When the ice sheet was moving out from the center, it gradually advanced across New England in a southerly or southeasterly direction, and as it moved, it overwhelmed everything in its path. Its motion was very slow but irresistible. It passed over hills and mountains, scraping the soil off the rocks and carrying blocks and fragments of them along with it. Pieces frozen into the ice acted as tools, and when they were pushed over rock surfaces by the great ice pressure, they cut grooves in the rock and wore it away. Some ledges were smoothed and polished by the great pressure of the ice. Such a ledge may be



A Glaciated Ledge on Foster Street, Brighton
Showing scratches and polished surfaces

seen in Franklin Park opposite the end of School Street. There is another on Foster Street, a quarter of a mile north of Commonwealth Avenue in Brighton.

When the ice pushed over a hill it smoothed off the north side and made it less steep. But when the ice moved away from the south side it froze onto the rock, pulling away great blocks, which it carried along as it moved onward. Thus many hills have steep slopes on the south side and gentle slopes on the north side. You can see this if you look at Big Blue from the west. This form may be seen in ledges as well as hills and is called Roche Moutonée. This name was given by a French geologist, who thought that rocks with this form looked like sheep with their heads down, and therefore called them sheep rocks.

The ice changed the appearance of the hills and made other minor changes in the topography. It widened those valleys which ran in the direction it was moving. The ice sheet did not make new rock hills or new valleys, but it greatly changed those which already existed. It covered all the hills about Boston, wore them down and modified the topography, but did not start new features of importance.

For more than a million years the ice sheet covered New England and advanced as far south as Long Island, N. Y. There were fluctuations in the climate, and sometimes the ice sheet melted back and then advanced again when there was more snow.

The advancing ice pushed up a ridge of débris

before it, which is called a moraine. The hills of Long Island represent a moraine formed by the farthest advance of the ice. During the retreat of the ice sheet temporary advances formed small moraines, and one of these may be seen at Arlington Heights. It extends westward from the corner of Eastern and Highland Avenues, and is marked by the great number of boulders.

There were two other great ice sheets in Canada at the same time. These three great ice sheets covered nearly all of Canada and the northern part of the United States. If we had been living here, then, we would have been obliged to go south to get away from the ice, and that is what the animals did.

We have proof that the ice was thick enough to ride over the top of Mount Washington in New Hampshire, sixty-three hundred feet high. On the summit are boulders of a rock, which is found at some distance to the northwest of the mountain but not nearer. The only way these boulders could have been carried to the top of Mount Washington was by the ice sheet.

As the glacier moved across the country it gathered up the soil, ground up rocks and picked up fragments, so that it contained an immense amount of clay, sand, gravel and boulders. Towards the end of the ice age the climate became milder and there was less snowfall to replenish the ice, which, therefore, advanced more slowly and finally began to melt back.

Then the débris which it carried was deposited under it, especially in hollows and on rock hills where the projections held back the ice. These deposits are known as glacial drift or boulder clay. This last name is very appropriate, as the material consists of clay, sand, gravel and boulders; in fact everything from clay to boulders.

Much of the boulder clay was deposited on rocky knobs and formed rounded hills known as drumlins. They have a rounded profile and an elliptical ground plan and are very common about Boston. Beacon Hill, Parker Hill, Corey Hill, Bunker Hill, Milton Hill, Wellington Hill in Dorchester, Waban Hill in Newton, the hills of Somerville, Everett, East Boston, Chelsea, Revere, and Winthrop, and many others are drumlins. Most of the islands of Boston Harbor are drumlins which have been surrounded by the sea.

Much of the city is built on drumlins. Although not quite as firm and solid as a hill of rock, the drumlins are very stable. The boulder clay is excellent for foundations, and those parts of the city built on drumlins are more solid than the parts on lower land.

Without the drumlins Boston Basin would appear much flatter than it does. There are some rock hills but they are not numerous. Many of the drumlins were deposited on rock hills, and excavations sometimes show the ledge. This can be clearly

A Drumlin with One End Washed Away by the Waves

seen on the north side of Parker Hill where the quarries have exposed the rock.

How can one distinguish a drumlin from hills of other types? First examine it to see if there is any ledge near its summit. Sometimes a large boulder partly buried looks like a ledge. If there is no ledge in the hill, examine the material of which the hill is made and see if it consists of clay, gravel and boulders. Some hills are made of sand and gravel without clay or boulders, but these were made in a different way and are not drumlins. If the hill consists of boulder clay, has an elliptical ground plan and a rounded profile, it is safe to call it a drumlin.

When the ice passed over ledges it tore off great blocks of rock and carried them with it. These were rubbed against each other and against the ledges, so that the corners were knocked off and the blocks were somewhat rounded. When the ice melted these blocks of rock, or boulders, were dropped wherever they happened to be. Sometimes they landed on hilltops, sometimes on other boulders and sometimes they were so delicately balanced that they can be rocked. They vary in size from pebbles up to the huge Madison Boulder in New Hampshire, which is eighty-three feet long and thirty-seven feet high. This is the biggest boulder known in New England.

The largest boulder near Boston is House Rock in Weymouth, which is thirty-seven feet high and forty-two feet long and weighs thirty-five hundred

Photograph by H. I. Orne

A PERCHED BOULDER IN MELROSE HIGHLANDS WHERE IT WAS DROPPED BY THE ICE SHEET

SHIP ROCK, PEABODY

A giant boulder left by the ice sheet

tons. It is near Essex Street, between Spring and Broad Streets, and is very easy to visit. Ship Rock in Peabody is another giant boulder. Although not as large as House Rock its position is much more spectacular. It is located on top of a high, rocky hill, a little north of Lynnfield Street, and is forty-eight feet long, thirty-two feet high and weighs about twenty-one hundred tons. These three giants are granite boulders.

In Franklin Park are many interestmg boulders, and that is one of the best places to study them. These are conglomerate boulders and are not as large as House Rock or Ship Rock. One of them is perched on the edge of a hill in a very striking position. It looks as though one might push it down the hill, but it is very firmly seated.

GLACIAL LAKE SHAWMUT

Probably you have never heard of Lake Shawmut. You will look in vain for it on the map, but at the end of the Ice Age it covered much of the Boston Basin.

In the preceding chapter we saw how New England was covered by a thick ice sheet. After many thousands of years the climate gradually became warmer, and the edge of the ice melted back northward. It melted faster on the west side of Boston than on the east side, and after Boston was free from ice, a long tongue of it extended across the mouth of the depression which is now Boston Harbor and connected with the hills of Hingham. This tongue of ice formed a dam across the outlet of the Boston Basin and held back the water from the melting ice, forming glacial Lake Shawmut. The surface of the lake was about seventy feet above the present sea level. The lake lasted many years and important deposits of sand and gravel were laid down in it.

How do we know about this lake which no human eye ever saw? We find in the vicinity of Boston extensive deposits of sand and clay which we know were laid down in quiet water, not in a running stream. There are no fossils in the clay, indicating that it was not deposited in the sea, but

in a cold glacial lake. None of the sand deposits of this lake are above an elevation of seventy feet, showing that the lake did not reach a higher level. When all of these facts are considered and compared with conditions in regions where glaciers are now found, we are convinced that Lake Shawmut did exist. The name was given by the geologist who discovered the proof of the lake, and he chose it because Shawmut was the Indian name for Boston and this lake covered the site of Boston.

For a long time the edge of the ice sheet was just north and east of the lake. The ice contained great quantities of clay, sand and gravel, and as it melted, streams of muddy water poured into the lake. The coarse gravel was deposited close to shore, the sand was carried out farther by the currents and then dropped, the clay remained in suspension for a long time and finally settled out in the quiet, deeper, central parts of the lake. The clay filled the lake up to an elevation of ten feet above the present sea level. When there were warm seasons the ice melted faster, the streams were larger and the stronger currents swept the sand farther out into the lake, depositing it on the clay so that layers of sand are found in the clay.

When the ice was melting there were many large streams on it and in caverns below its surface. The ice contained much sand and gravel, and this was deposited in the icy beds of these glacial streams

A Glacier and Glacial Lake Such as Once Existed Here

just as rivers today deposit sand and gravel in their channels. When the ice finally melted away, the deposits in the glacial river beds were dropped down on the ground, and formed long, winding ridges known as eskers. Where the glacial stream reached the edge of the ice, it built out a delta of sand which

An Esker Partly Submerged in the Charles River
Near Norumbega Park

now forms a sand plain. Eskers and sand plains are common about Boston.

In most clay pits or sand banks layers, or strata, are to be seen. Careful examination shows that some of the layers are of coarser material than the others. The coarse layers were deposited during floods when the sand was swept out into the lake. When there were no strong currents only mud was deposited, forming the fine grained layers. Sedi-

An Esker Near Roberts Station in Weston
The cut through it shows the material of which it is made

ments deposited in water are sorted and stratified, and for this reason sedimentary rocks are often called stratified rocks.

Ripple marks, very small parallel ridges made by the waves or currents, may often be seen on

Stratification and Ripple Marks in a Sand Bank Near Mount Hope Station

beaches or in sandy or muddy river beds. Sometimes they were buried by more sand, and we find them in sand banks or even in solid sandstone and slate. They often give very beautiful effects and bring to mind a picture of the water rippling on the beaches in bygone days.

The ice did not melt back regularly, but in some places it retreated faster than in others. Great blocks broke off from the main ice sheet and some

of these floated away as icebergs. Sometimes large stones and boulders were frozen into these icebergs, and when the ice melted the stones and boulders were dropped. We occasionally find boulders in the clay. We know that the currents in a lake could not carry these stones, and the only way they could have been brought there was by floating icebergs.

Some of the large blocks of ice that became separated from the ice sheet did not float away as icebergs but became buried in the sand that was washed out from the ice. When they finally melted the sand which covered them slumped down leaving large depressions. These are called kettle holes because they look like the inside of a kettle. They vary in size from a few feet to a mile or more across. There is a beautiful kettle hole directly in front of the Children's Museum in Jamaica Plain. Some of the kettle holes became filled with water and now contain ponds. Jamaica Pond, Spy Pond, Fresh Pond and most of the other ponds about Boston were made in this way, and are called kettle ponds.

The deposits of sand and clay are of great importance. Much of the city is built on the clay. This is not a good foundation material, but by taking proper engineering precautions, buildings can be constructed safely on it. The clay is used in the brick yards of Everett, Chelsea, Revere and Cambridge and formerly the sand was used in the old glass factories of Somerville.

Lake Shawmut covered Old Boston, the Back Bay, South Boston, East Boston, Chelsea, Revere, Everett, Somerville, Cambridge and parts of Malden, Medford, Arlington, Brighton, Brookline, Roxbury and Dorchester. Long arms of the lake extended up the Mystic, Charles, Neponset and other valleys. Many drumlins rose above the surface of the lake as islands. The drumlins are made of boulder clay which is very firm. On the upper part of the drumlins there is no sand or clay, therefore buildings located on drumlins have better foundations than buildings on the clay of the surrounding lowlands.

Finally the tongue of ice which formed the dam holding back the lake melted away and Lake Shawmut drained to the east and was no more. This region was then higher than at present and the sea was farther away. We know this because the clay deposited in Lake Shawmut was bluish and is still so, except where it has been exposed to the air and has been oxidized. Clay contains a little iron and air causes the iron to rust and color the clay yellow. When it is under water the air can not get at the iron to oxidize it and the clay remains bluish. We find that the upper part of the clay is often yellow, and yellow clay has been found in excavations thirty feet below low tide, showing that since the disappearance of the ice the land has been at least thirty feet higher than it is now.

THE BIRTH OF OUR MODERN RIVERS

The great ice sheet completely covered New England for many thousands of years. It contained great quantities of débris: clay, sand, gravel and boulders which it had scraped up as it moved across the country. When the ice finally melted away it dropped all this débris. Where there was more dirt in the ice more material was dropped. The country thus became covered with an irregular layer of glacial drift or boulder clay. In some places this was very thick, often more than a hundred feet; in others it was thin; and in still others there was none at all, the bare rock being left at the surface. During the melting of the glacier great quantities of clay, sand and gravel were washed out of the ice by the numerous streams which flowed from it. These dropped their sediments, forming thick layers of clay and sand. The blue clay which underlies much of Cambridge was formed in this way.

These thick deposits of boulder clay, blue clay, sand and gravel covered much of the country and filled up many of the old valleys. After the ice was gone streams formed again and flowed towards the sea, but many of the old valleys were filled with glacial drift which turned the streams into new courses. They wandered this way and that, where-

ever they found the lowest depressions. When the stream came to a hollow a pond or lake was made by the water filling it before proceeding on its way. Thus these new streams became very crooked with

SKETCH MAP OF THE CHARLES RIVER
Showing its circuitous course, and Mother Brook which connects the Charles and Neponset Rivers, thus making an island of Boston.

many ponds and lakes in their courses. If you look at a map of the Charles River you will see that it is a very crooked stream. From its source to its mouth the distance in a straight line is twenty-five miles, but the course of the river measures sixty-nine miles.

Before the Ice Age the Merrimac flowed through Boston, but after the ice sheet had melted away and

the new Merrimac started to flow to the sea, it found parts of the old valley filled with glacial drift. The river followed this valley down to Lowell. In places the old channel was blocked with drift and the stream had to flow a little to one side, but it kept to its broad valley. Just south of Lowell the old valley was so completely blocked with drift that there was no passageway for the water, which found the lowest place between the hills and flowed northeasterly, finally entering the sea at Newburyport, more than thirty miles from its old mouth near Boston.

The old valley, now buried under glacial drift, was abandoned. Thousands of years later man dug the Middlesex Canal and then built the Boston and

The Middlesex Canal and the Modern Railroad at Woburn in the Valley of the Pre-Glacial Merrimac

Lowell Railroad, both of which followed the general course of this pre-glacial valley. Thus, although the valley was partly filled up and abandoned by the river thousands of years ago, it is still of use to us.

The new Merrimac flowed over the glacial drift from Lowell to Newburyport and soon cut a valley in the soft débris. In places it came upon buried ledges, where it was difficult for the river to cut into the rock, and therefore rapids and falls were formed. The falls at Lowell, Lawrence and Haverhill exist, because at these places the river cut down on hard rock. Other rivers besides the Merrimac had to find new channels. They frequently cut down on hard rock, and for this reason falls and rapids are numerous in New England rivers. The falls in the Charles and Neponset Rivers were made in this way. The numerous falls furnish water power, which has caused many mills to be started in New England. The mills at Lowell and Lawrence were located there because water power was available.

The Mystic has its source in the abandoned valley of the old Merrimac. The Mystic Lakes were kettle holes where great blocks of ice were buried in the sand washed out from the glacier. The river filled these kettle holes and made the lakes. At Arlington the Mystic leaves the valley of the old Merrimac and flows easterly into the harbor.

The modern Charles is not only very crooked but has several falls. Before the ice age there was a

river following somewhat the same course as the lower part of the Charles, but it was not so crooked and it did not have waterfalls. The upper part of the Charles River valley was then drained by other streams, but the courses of these old rivers were now blocked with glacial drift, causing a new stream to form, which wandered about seeking the path of least resistance, and thus the present Charles was born. This accounts for its extremely crooked course which you will have noticed, if you have been on the river near Spring Street or Dedham. At several

Courtesy of the *Boston Globe*

NEWTON UPPER FALLS

A narrow gorge cut by the Charles River since the Ice Age. The falls are used for water power

places the Charles cut down on buried ledges, and in this way Newton Upper Falls and Newton Lower Falls were formed. These provide water power which was used by the early settlers and is still being used. The gorge under Echo Bridge at Newton Upper Falls has been cut in the conglomerate by the Charles since the disappearance of the ice sheet, and the river has not had time to make a wide valley there. In time this gorge will be widened like the remainder of the valley.

The old Charles River joined the old Merrimac River at Allston. The new Charles found the valley of the old Merrimac buried under two hundred feet of clay and was forced to seek a new course to the sea. It therefore crossed the buried valley of the old Merrimac at Allston and made its channel around the north end of Boston Neck. It carved its valley in the blue clay and the boulder clay and was responsible for the form of Boston Neck.

The numerous ponds and lakes formed after the ice sheet melted away have been very important to man. Some of them have been used as reservoirs for water supplies and from many ice is cut. They greatly beautify our landscape, and for this reason their shores are chosen for pleasure resorts where the inhabitants of our cities can find rest and refreshment. They also attract thousands from other states. In many ways the Ice Age changed the face of the country and greatly affected our daily life.

THE MAKING OF BOSTON HARBOR

When the ice melted away from New England the land stood somewhat higher above the sea than it does now, and the sea was farther to the east. New rivers developed and eroded new valleys. Gradually the land sank and the sea came into the valleys, flooding them and forming long bays. Hills that were surrounded by the sea became islands, and ridges that projected out into the water formed peninsulas. As there were many valleys, hills and ridges along the New England coast, many bays, islands and peninsulas were formed, making our coast very irregular.

The sea came into the valleys of the Charles, Neponset and Mystic rivers and the other streams about Boston, thus making Boston Harbor and the other bays that indent our coast. These flooded river valleys are called drowned valleys. All the deep bays of the New England coast have been formed in this way. Drowned valleys are especially well developed on the coast of Maine.

Where the invading sea surrounded hills, islands were formed and the shape of the island depended on the shape of the hill. Drumlins have a regular outline and they produced islands of regular shape, but those formed from rock hills are usually very

irregular and rugged. In this way the numerous islands of Boston Harbor were made. Most of them are drumlins and are quite different in appearance from the rugged rock islands of the coast of Maine.

The other islands of the New England coast have a similar origin, since they were formed by the

Drumlin Islands in Boston Harbor Seen from Houghs Neck

sinking of the land and the surrounding of the hills by the sea. Drumlin islands are characteristic of Boston Harbor and rock islands of the coast of Maine.

When a hill was connected with higher land by a ridge and the sea came in about it, a peninsula was made. In this way Boston Neck, Charlestown Neck, Dorchester Neck and the numerous peninsu-

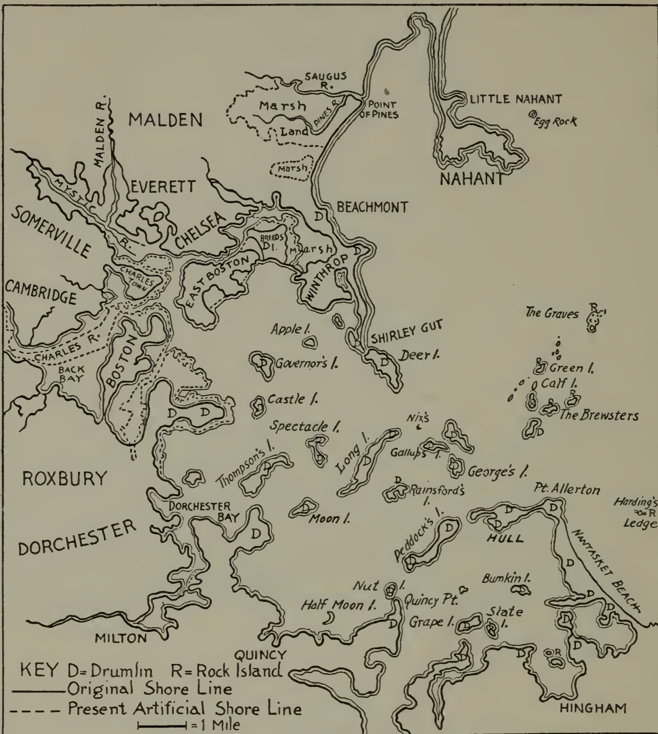
las of the New England coast were given their present aspect.

After the sea flooded a shallow valley the streams deposited mud and partly filled it, making a salt water marsh. There was much shallow water about Boston in which mud collected, and salt marshes are a frequent feature of our shores. A coast like ours with its numerous deep bays, islands and peninsulas is made by the sinking under the sea or submergence of land topography. This is known as a shore line of submergence. If you look at the country about you anywhere near the coast in New England and imagine what would happen if the sea were to rise a hundred feet, you will see that the new shore line would greatly resemble the present shore line. It would have deep bays, long peninsulas and numerous islands.

The New England coast is a typical shore line of submergence, and is in strong contrast to the shore line produced by the raising of the land and the uplifting of the sea bottom to form new land. The bottom of the sea is fairly smooth and level and when it is uplifted to form land, a straight shore with long beaches and no deep bays is produced. The east coast of Florida is typical of this kind of shore. It is called a shore line of emergence, since it is caused by the emergence of the sea bottom to become new land.

If you look at a map and see a very irregular

shore you can be certain that it is a shore line of submergence and was the result of the sinking of the



MAP OF BOSTON HARBOR
Showing the original and present shore lines

land under the sea. But if the map shows a straight shore with long beaches and few bays, then you know that it is a shore line of emergence, and that the ocean bottom has been lifted up out of the water.

When you sail down Boston Harbor or cruise along the coast of Maine, it is interesting to know that you are sailing over a drowned land on which animals and Indians probably roamed at one time. We know that the Indians lived here before the sea rose to its present level. In digging for the subway a fish weir was found far below the surface of the street, eighteen feet below the level of the sea. This proves that men were living here several thousand years ago and that the shore was different then. The sea rose very slowly, so slowly that the Indians living here probably never knew that anything was happening.

Some think that the land is still slowly sinking, about a foot a century, and that eventually Boston will be covered by the sea. Geologists are not agreed as to whether it is sinking or not, and it is very difficult to prove because the movement is so extremely slow. If the city were several thousands of years old we could tell by noticing whether any old buildings had sunk under the water. At Pozzuoli in Italy is an old temple which was sunk thirteen feet under the sea, and has been raised up again in the last few centuries. On the New England coast are tree stumps which have sunk under the water, but we do not know how long they have been there.

Even if our land is sinking slowly there is no cause for alarm. It would be hundreds of years before we could notice any difference. Man is con-

tinually building up the land and, even if the sea is rising a foot a century, it will be a long time before there can be any serious trouble.

We have now traced the development of the Boston region up through the formation of the harbor, but some finishing touches were still to be applied before the white man appeared. Our beautiful beaches, Nantasket, Revere and Nahant, did not exist, and the harbor was partly open to storm waves because the protecting peninsulas of Nantasket and Point Shirley had not yet been formed.

THE MAKING OF BOSTON'S BEACHES

When the sea rose and flooded the shore, after the Ice Age, it came into the valleys, drowning them, thus forming many bays. Where several valleys came together a large bay was formed, and this was the origin of Boston Harbor. The islands were hills which were surrounded by the sea. When the harbor was first formed it did not appear as it does now, because the long beaches which separate the harbor from the sea had not yet been made.

If you look at a topographic map of Nantasket or walk from Pemberton to Nantasket you will see that there are a number of hills connected by stretches of sandy beach. At the southern end of the beach is Atlantic Hill. This is a rock hill and is separated from the mainland by Straits Pond, also known as the Sea of Galilee, and Weir River. North of Atlantic Hill are Sagamore Head, White Head, Strawberry Hill, Great Hill at Point Allerton, and Telegraph and Thornbush Hills in Hull. These are all drumlins formed of boulder clay by the great ice sheet. There is no ledge on Nantasket Beach and only one small ledge of slate in Hull, near the foot of Telegraph Hill. When the land sank these hills became islands.

If you examine Great Hill you will see that the

eastern end of it has been washed away by the waves. The numerous boulders which were in the boulder clay of the hill have been strewn over the sea bottom near the shore, where they help to protect it from the attacks of the waves. From the summit of the hill these boulders can be seen at low tide. They show how much longer the hill was before the sea began to wear it away. The pebbles washed out have been carried westward by the currents and thrown up on the shore by the waves, forming Stony Beach which connects Great Hill with Telegraph Hill. The finer débris was carried farther westward by the currents and waves and formed the projecting point, or spit, known as Windmill Point at Pemberton. This would have undoubtedly connected Pemberton with Peddocks Island except for the very strong tidal current, which rushes through Hull Gut when the tide is going out. This current sweeps the sand away faster than the other currents coming along the shore can deposit it, thus keeping the Gut open.

While these events were taking place great storm waves broke in the shallow water between the islands south of Point Allerton and stirred up the sandy bottom. The sand was thrown up in front of the breakers, forming a beach which connected the islands. The beach was built forward by the waves until Strawberry Hill was left some distance back from the shore. You can see a bluff on the easterly

Courtesy of the *Boston Globe*

LYNN BEACH

A barrier beach connecting Lynn and Nahant

end of Strawberry Hill, showing where the waves once cut into the hill. These islands were thus tied together by Nantasket Beach and in a similar way Atlantic Hill was tied to the mainland by Crescent Beach. This beach shut off a small bay from the sea and caused the water in it to flow westward through Weir River, and thence into the southern part of Boston Harbor. The closing of this small bay formed Straits Pond which lies between Atlantic Hill and the mainland.

Beaches built by the waves in this manner are called barrier beaches, because they form barriers, often protecting harbors behind them. Islands tied together as these are, or connected to the mainland by beaches, are known as tied islands. Nantasket Beach and Hull thus consist of a number of islands tied together by barrier beaches.

At Nantasket you can see a great deal of geology in a short distance. The mainland south of Nantasket, in the town of Cohasset, is composed chiefly of granite and diorite. These same rocks are found in most of Cohasset, Scituate, Hingham and Weymouth. At the south shore of Straits Pond there is a sudden change in the rocks, since this is the southern border of the Boston Basin. Here is the great fault which separates the granitic rocks from the conglomerates and lavas of the Basin, and north of this fault there is no granite. In Atlantic Hill are layers of conglomerate alternating with layers of lava

and volcanic tuff. North of this hill there is no solid rock except a ledge of slate in Hull. The rest is either boulder clay or sand and pebbles. In a short walk we can cover millions of years of geology. We begin in Cohasset on the granite, hundreds of millions of years old, and walk northward. When we cross the great fault we come upon conglomerate, formed millions of years later than the granite. North of Straits Pond we come to the lava, of the same age as the conglomerate, and at the north foot of Atlantic Hill we step upon Nantasket Beach which was built by the sea during the last few thousand years.

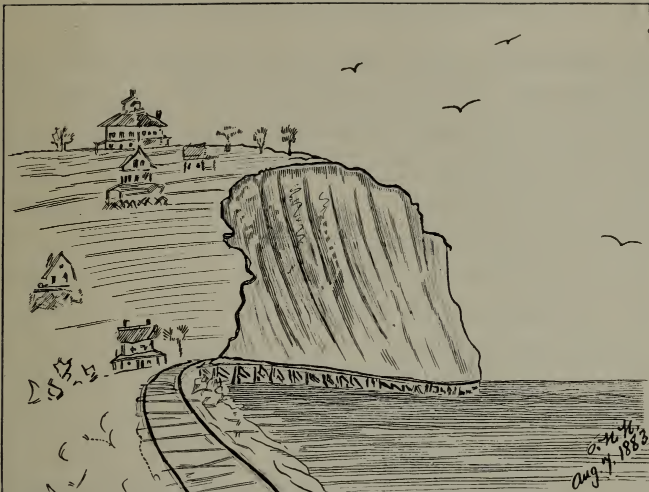
Nantasket Beach is not the only example of barrier beach and tied islands about Boston. Beachmont, Grovers Cliff, Great Head at Winthrop and the small hill at Point Shirley are all drumlins and were formerly islands. The sea attacked Grovers Cliff, where Fort Heath now stands, and washed away part of the drumlin. The boulders which were in it have been left on the sea bottom just off shore, where they form a boulder pavement similar to the one described off Point Allerton. The finer materials were carried north and south by the currents and were thrown up on the shore by the waves, thus forming the barrier beaches which connect Grovers Cliff with Beachmont and Great Head.

In a similar way the waves attacked Great Head and eroded it, leaving an extensive boulder pave-

ment which can be plainly seen from the top of the hill. In fact, at low tide you can see a crescent shaped bar offshore which marks the eastern end of the hill before it was washed away by the waves. This bar is made of the boulders and pebbles which were in the hill. Some of the material from this hill was washed northwards and used by the waves in building Winthrop Beach, which connects Grovers Cliff and Great Head. The remainder of the material from the hill was washed southward and built a long spit extending out to Point Shirley. This spit would have tied Deer Island to the mainland except for the strong tidal currents which rush through Shirley Gut and keep the channel open, just as the currents sweeping through Hull Gut keep the spit there from connecting with Peddocks Island. When Winthrop Beach was first formed, a bay was left between the hill which forms the main part of Winthrop and the beach. This bay has now been partly filled up with salt marsh.

A long barrier beach was built out north from Beachmont and the bay behind it was partly filled with salt marsh. This is Revere Beach, the northern part of which is still separated from the mainland by a bay known as Pines River. Saugus River is a branch of this bay. It is so shallow and there is so much salt marsh in it that it can not be used as a harbor.

There is no better place near Boston to witness



Sketch by Dr. Oliver H. Howe

Winthrop Great Head in 1883 before the Railroad had Been Destroyed by the Waves

Winthrop Great Head in 1927

Showing the new sea wall

the ceaseless warfare of the sea than at Winthrop Head. The sea is a relentless enemy constantly attacking the land, sometimes held in check but always returning to the attack with renewed vigor. Time is of no account; what it can not do today it will do tomorrow, or next year, or a thousand years from now. The sea is like a mighty giant who hates all irregularity and wishes to make everything straight and uniform. Here, in New England, it found a rugged, most irregular coast with long peninsulas and deep bays. It at once set itself to the task of straightening the shore, as if its battle cry were "Down with the hills, fill up the bays!" Gradually the hills are worn away by its resistless attacks, and barrier beaches are built across the bays with the débris from the hills, producing a straighter shore line. Thus the giant pursues its endless task of reducing all to uniformity.

Forty years ago there was a railroad on the seaward side of Winthrop Head, but finally the attacks of the sea became too dangerous and the railroad was abandoned. Now there is no vestige of it left and the sea is gnawing back the high bluff towards the water tower. You can see the change from year to year. A drain pipe, formerly buried in the ground, now projects out into space with some of the earth which covered it still balanced on it. A strong sea wall has just been built to protect the shore from the waves and prevent them from continually eating

away the hill, and causing the water tower to crash into the sea. If man is not successful in holding back the sea it will in time entirely remove this hill. Then when the source of the materials of which the beaches are built is gone, the sea will break through the barrier beaches and begin to attack the main part of Winthrop. This will take thousands of years and probably man will be able to prevent it.

We can see these changes in the shores of the islands and headlands of Boston Harbor because they are made of boulder clay and sand, and the sea does its work with comparative rapidity. The sea is also attacking the rocky shores, north and south of Boston, and very slowly wearing them away, but the change is so slow that we do not notice it.

There is still another example of tied islands and barrier beaches near Boston. If you look at a map which shows Nahant you can see that it is almost an island. Formerly Nahant and Little Nahant were rocky islands separated from the mainland by a mile and a half of shallow water. Little Nahant was tied to Nahant by a short barrier beach, and a long barrier beach, Lynn Beach, tied Nahant to the mainland. These beaches were formed by great storm waves breaking in shallow water and throwing up the sand in a ridge until it rose above the water. Without these beaches Nahant would consist of islands and Lynn would have no harbor. Lynn Beach, also called Nahant Beach, is a beautiful

example of a barrier beach, one of the best near Boston.

Barrier beaches are common along the New England coast, and many of our beautiful beaches are of this character. Duxbury Beach and Plum Island near Ipswich are good examples, and there are others on Cape Cod. Marblehead Neck is another barrier beach which ties an island to the mainland and forms a beautiful, well protected harbor. Provincetown, at the end of Cape Cod, is on a great spit which was built out by the currents from the sand worn away from the Cape. The end of this spit is curved and is called a hook.

The building of barrier beaches and the tying together of islands have had a very important effect on the life of our city. Without the long beaches Boston Harbor would not be so well protected from the storms and Lynn Harbor would not exist. We also would lack our beautiful beaches where it is so pleasant to go on a hot summer day.

BOSTON AS THE WHITE MAN FOUND IT

What did the white men find here when they first sailed into Boston Harbor over three hundred years ago? Of course there were no lighthouses or beacons in the harbor to guide their course and they were obliged to proceed carefully through narrow and shallow channels, not knowing when they would run aground. On the shores there were no houses or structures of any kind except a few Indian wigwams.

It is difficult for us living in this great city to imagine how it looked before any of the works of man were constructed. Many of the islands were wooded and trees were much more numerous than at present. Imagine that you were an explorer sailing into Boston Harbor, or Massachusetts Bay as it was first called, three or four centuries ago. As the ship neared the land the watchers could at first see only the hilltops, then, as the ship drew nearer, two long peninsulas with a group of hilly islands between them became visible. These islands are now called the Brewsters and consist of Great, Middle and Outer Brewster, Calf Island, Lighthouse Island and smaller islets and rocks. These rocky outer islands presented a very rugged appearance. In fact they have not changed and are still wild and desolate. The ship threaded its way through the uncharted

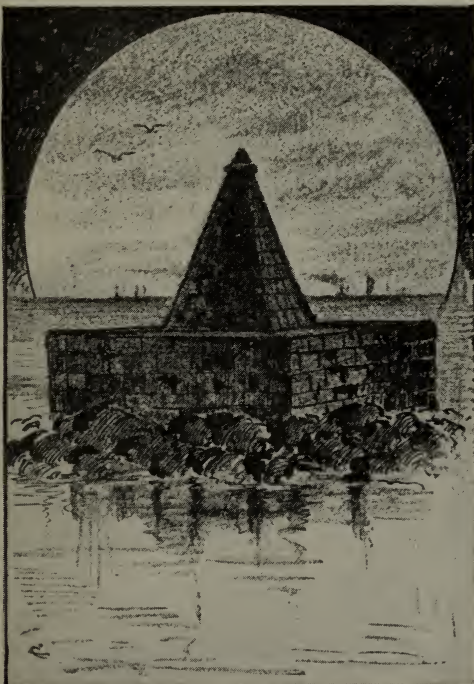
channels and among the rocks and hidden bars. As it sailed farther into the bay the character of the islands changed. They were less rugged and had rounded hills, some of which were wooded; these are the drumlins which we have already described.

Just south of the main ship channel, between Gallops Island and Long Island was another island which you cannot find on any modern map, but instead there is a beacon called Nix's Mate. This marks the site of an island which had an area of twelve acres in 1636 and rose above the water with bold bluffs. In Colonial days sheep were pastured on it. There is an interesting legend about the island. According to this story a Captain Nix was murdered at sea on his ship and the mate was charged with the crime and hung on this island. He claimed that he was innocent and said that as proof of his innocence the island would be entirely washed away by the angry sea. His prophecy came true for

From "Kings Handbook" of Boston Harbor

NIX'S MATE IN 1700

nothing is left of it now except a gravelly shoal on which stands a large stone beacon, erected over a century ago. Perhaps the mate was a good geologist



From "Kings Handbook" of Boston Harbor
THE BEACON
Marking the site of Nix's Mate

and saw that the island was doomed to be washed away by the waves. However it is certain that the island was used as a place of execution for pirates and others who committed crimes at sea.

As the ship of the early explorer continued up the harbor it passed other islands which are little changed except that they are now somewhat smaller, for even in the harbor the waves are ceaselessly at work wearing away the islands and headlands. The rock islands have not suffered any appreciable change in the last three hundred years, but the drumlin islands, made of boulder clay, have been much eroded, and in some cases, as we have just seen, totally destroyed.

The ship passed between Castle Island and Governors Island, and just beyond the latter, between it and East Boston, formerly called Noddles Island, was another island which you cannot find now. This was called Bird Island and it has since been entirely washed away. Where it stood are now the Bird Island Flats and these have been partly removed by dredging. Bird Island was also used as a place of execution for pirates. It is interesting to note that the two islands on which pirates were executed were the only ones in the harbor which have entirely disappeared beneath the waves. It seems as though nature rebelled at the defiling of her beauty spots and sank them under the water to cleanse them.

The ship was now in the inner harbor but there were no wharves or warehouses along the shores. Even the hills were different. Boston Neck was crowned with three hills: Beacon Hill, Copps Hill and Fort Hill. The highest of these, Beacon Hill,

AN OLD MAP OF BOSTON HARBOR. SHOWING NIX'S MATE AND BIRD ISLAND

was also called Tri-mount because it had three summits, and this was the name first given to the settlement here before it was called Boston. Tremont Street takes its name from Tri-mount and is thus a reminder of this early feature of Beacon Hill. When Boston was first settled this hill was about one hundred and eighty feet high, but its present height is

Tri-mount, or Beacon Hill, from Charlestown, as It Looked Three Centuries Ago

only one hundred and five feet due to the work of man.

The other hills were not so high or large. Copps Hill was formerly called Windmill Hill because the first windmill in Boston was set up here. This was brought from Watertown in 1632, since there it would not grind the corn except with a westerly wind. At its new location in Boston it is certain that the mill ground industriously with an east wind as well as with a west wind. Copps Hill then rose precipitously fifty feet from the water and it has not been much changed

since. The Old North Church stands on the south slope of this hill and the burying ground is on its summit. South of Copps Hill, across a shallow cove, was Fort Hill, first called Corn Hill because it was one of the early planting grounds of the settlers. A fort was built on it in 1632, and since then it has been called Fort Hill. It rose eighty feet above the harbor and was steep on the north side, but now only a gentle hillock thirty feet high is left. It was destroyed by man and not by the rains or waves.

The hills are not the only features that were different three hundred years ago. Broad bays surrounded Boston and almost completely isolated it from the mainland. The only connection with the land was by Boston Neck which was very narrow, in one place only a few hundred feet wide, and was almost covered by high tides. Charlestown Neck was also a peninsula connected to the mainland by a narrow isthmus or neck. These changes and many others will be described in a later chapter.

SHAKING UP THE PURITANS

In a preceding chapter we learned of earthquakes a quarter of a billion years ago, but it is not necessary to go that far back for records of earthquakes in Boston. Many of you probably remember the shocks of January and February, 1925. They were mild compared with the earthquakes that shook the Puritans.

The first severe earthquake in Boston which was recorded in human history occurred in June, 1638. It was especially severe at Plymouth. The following account is quoted from Bradford's History:

"This year about y^e^ 1. or 2. of June was a great & fearfull earthquake; it was in this place heard before it was felte. It came with a rumbling noyse, or low murmure like unto remoate thunder: it came from y^e^ norward, & pased southward. As y^e^ noyse aproched nerer, the earth begane to shake and came at length with that violence as caused platters, dishes, & such like things as stood upon shelves, to clatter and fall down; yea persons were afraid of y^e^ houses themselves. It so fell out y^t^ at y^e^ same time diverse of y^e^ cheefe of this towne were mett together at one house, conferring with some of their friends that were upon their removall from y^e^ place, (as if y^e^ lord would hereby show y^e^ signs of his displeasure,

in their shaking a peeces and removalls one from another.) However it was very terrible for y^e time, and as y^e men were set talking in y^e house, some women and others were without y^e doors, and y^e earth shooke with y^t violence as they could not stand without catching hould of y^e posts & pails y^t stood next them; but y^e violence lasted not long. And about halfe an hower, or less, came an other noyse and shaking, but nether so loud nor strong as y^e former, but quickly passed over, and so it ceased. It was not only upon y^e sea coast, but y^e Indeans felt it within land; and some ships that were upon y^e coast were shaken by it. So powerful is y^e mighty hand of y^e lord as to make both the earth & sea to shake, and the mountains to tremble before him when he pleases; and who can stay his hand?"

In those days no one thought of studying the rocks, and the real causes of earthquakes were not known. Then people thought they were due to the hand of the Lord or were the work of the devil. Since then we have learned that earthquakes are due entirely to natural causes. The earth is very hot inside and cool outside. This great difference in temperature sets up strains, which cause the rocks to crack and break, forming a fault. When they break and move there is a tremendous jarring. Sometimes earthquakes are caused by volcanic explosions, but most of the great shocks are due to breaking and movement of the rocks.

This earthquake of 1638 was a severe shock. There were no large buildings then, only low log cabins, and none of them were destroyed, but if there had been high buildings, such as we have now,

EARTHQUAKE CRACK THAT CUT THROUGH A FENCE AND MOVED IT OUT OF LINE
The picture shows the fence after it had been mended

much damage would probably have been caused. We know little about earthquakes here before the white man came, because the Indians did not pay much attention to them. The Indians had no large buildings but lived in small wigwams, and earthquakes did them no harm. The principal danger

from earthquakes is caused by the fall of buildings. Man has put up structures without thinking about earthquakes and sometimes they are thrown down causing great loss of life, but there is never much danger outside of cities and away from buildings.

The next severe earthquake in Boston came in February, 1663. It threw dishes from the shelves and broke some chimneys but did no worse damage here. In Quebec, near the fault that caused the earthquake, the shock was very severe; trees were uprooted, chasms formed, landslides started and the courses of rivers changed.

In October, 1727, there was a severe earthquake in Newbury, near Newburyport. This shock was of equal intensity in Lynn. In those days most of the records were kept by the ministers. The Reverend Mathias Plant, minister of Newbury, has left a very interesting account of this shock as follows:

"October 29, 1727, being the Lord's day, about 40 minutes past ten the same evening, there came a great and rumbling noise; but before the noise was heard, or shock perceived, our bricks upon the hearth rose up about three quarters of a foot; and seemed to fall down and loll the other way, which was in half a minute attended by the noise or burst. The tops of our chimneys and stone fences were thrown down; and in some places (in the lower grounds, about three miles from my house) the earth opened and threw out some hundred loads of earth of a

different color from that near the surface. . . . It continued roaring, bursting and shocking our houses all that night. Though the first was much the loudest and most terrible, yet eight more that came that night were loud and roared like a cannon at a distance. It continued roaring and bursting 12 times in a day and night, until Thursday in the same week, and then not so frequent; but upon Friday in the evening, and about midnight, and about break of day upon Saturday, three very loud roarings."

The people imagined that they smelled sulphur and thought this proved that the earthquake was the work of the devil. They were so badly scared that many went to church who had not done so before, and the ministers record that there was a revival of religion. During the next fourteen years Mr. Plant recorded one hundred and twenty shocks. If we had to live through a series of shocks like that probably we would be badly scared and worried. However, this shock of 1727 was not the worst which has been felt in Boston.

On the eighteenth of November, 1755, seventeen days after the terrible earthquake at Lisbon, Portugal, which killed thousands of people, there occurred the greatest earthquake of historic times in Boston. A careful account was left by Professor John Winthrop of Harvard College. By accident the exact time of the shock was recorded. Professor Winthrop had regulated his clock the previous noon and had

enclosed a long glass tube inside the tall case of the clock for safety. This tube was thrown against the pendulum by the first shock, stopping the clock and recording the exact time of the earthquake, which was four hours, eleven minutes, and thirty-five seconds after midnight.

The damage done in Boston was considerable according to Winthrop: "Besides the throwing down of glass, pewter and other movables in the houses, many chimneys were levelled with the roofs of the houses and many more shattered and thrown down in part. Some were broken off several feet below the top, and, by the suddenness and violence of the jerks, canted horizontally an inch or two over, so as to stand very dangerously. Some others were twisted or turned around in part. The roofs of some of the houses were quite broken in by the fall of chimneys; and the gable ends of some brick buildings were thrown down and many cracked. The vane upon the public market house was thrown down; the wooden spindle which supported it, about five inches in diameter, and which had withstood the most violent gusts of wind, being snapped off. . . . A distiller's cistern, made of plank, almost new, and very strongly put together, was burst to pieces by the agitation of the liquor in it; which was thrown out with such force as to break down one whole side of the shed which defended the cistern from the weather."

According to other accounts the damage was greatest on the low loose ground near the harbor. Here the streets were almost covered by the bricks that had fallen. It was estimated that not less than

Man Standing in Fissure in Ground Made by an Earthquake

one hundred chimneys were levelled with the roofs, and fifteen hundred shattered and partly thrown down.

In Scituate the earthquake was even more severe than in Boston. Chimneys were shaken down, roofs crushed in and many houses disjointed and nearly destroyed. In swampy ground waterspouts burst out and a spring was started which is still flowing.

No one was killed by this earthquake because it came at night when nobody was on the streets, but if it had happened in the daytime there certainly would have been some loss of life from the falling bricks.

Such an earthquake today would undoubtedly cause great damage and loss of life, because the city is so much larger and the buildings are higher. It is now over one hundred and seventy years since this earthquake, and there have been no severe shocks in Boston during that interval, but this does not mean that there will never be any more severe earthquakes in Boston. However, there is no need of being alarmed about it. Strong buildings will not be injured, but weak structures must be avoided.

These earthquakes are believed to have been caused by movement on a fault just off the coast under the sea, or by a fault in the St. Lawrence Valley, but not by any of the faults in the Boston Basin.

THE WORK OF MAN

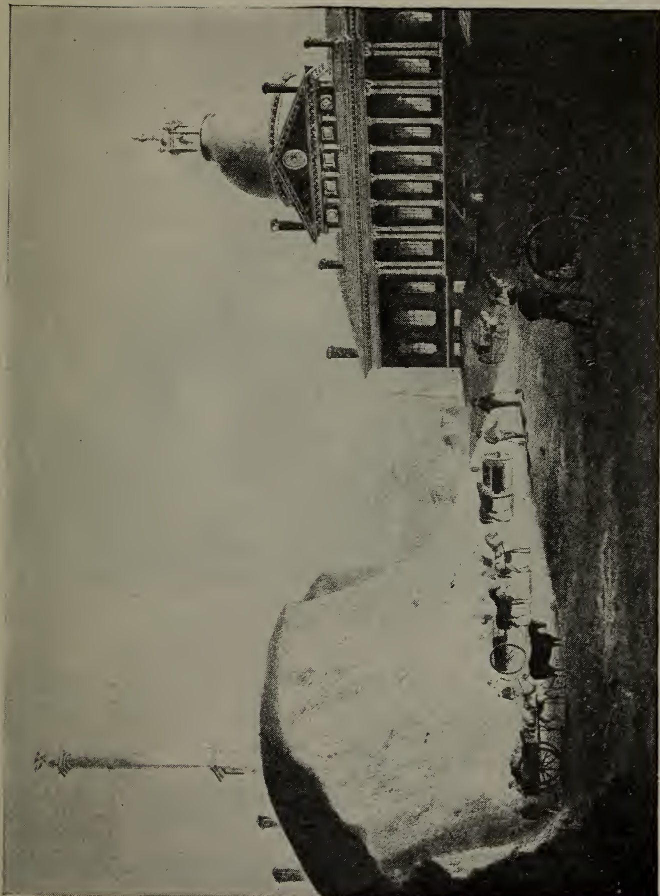
When Blackstone, the first white settler in Boston, came here, nature had almost finished her work in making the topography of Boston. However, if we examine the old maps and pictures, we see that there have been many changes since then. The present shore of the inner part of Boston Harbor has almost no relation to the shore of three hundred years ago. The changes are entirely the work of man. Shallow bays have been filled in, stream courses changed and some obliterated, ponds filled up and many more constructed, ledges blasted away and other changes made.

Boston Harbor had a very irregular shore line with numerous long, narrow peninsulas, between which were shallow tidal bays or estuaries, with extensive areas of salt marsh along their shores. It was natural that the first settlers should have located on these peninsulas, or necks, as they were called, and Charlestown, Boston and Dorchester Necks were settled early. Here they found deeper water near the shore for their ships than they could find in the estuaries. Also the necks were easily defended in case of attack, and high, dry land was more plentiful on the necks than along the marshy shores of the estuaries, such as the lower Charles and Mystic

MAP OF BOSTON IN 1775

rivers. The first group of colonists came to Charlestown Neck but they found a scarcity of good drinking water and soon most of them moved to Boston Neck where Blackstone showed them a spring. It was located where Spring Lane now is, between Water and Milk Streets.

East Boston was known as Noddles Island in the Colonial days, and it was separated from the mainland by tidal channels. It consisted of several drumlins with low areas in between and extensive mud flats along the shores, especially on the east shore. Old Boston was almost an island, as the neck, where Dover Street now crosses Washington Street, was only a few hundred feet wide. Washington Street, then known as Orange Street, the only road to the mainland in Colonial days, was built along the narrow part of the neck. Indeed, Washington Street is now the only road out of Boston which does not pass over made land. Between Boston Neck and Cambridge was the broad but shallow Back Bay, much of which was mud flats at low tide. Between Boston and Dorchester Neck was the South Bay, which almost joined the Back Bay but was separated from it by the narrow part of Boston Neck. The South Bay was somewhat deeper and was more used for shipping. The old shore line ran where Beach Street now is. There were wharves along Washington, or Orange Street, and at one time the people complained because the bowsprits of the ships moored



THE SUMMIT OF BEACON HILL BEING REMOVED

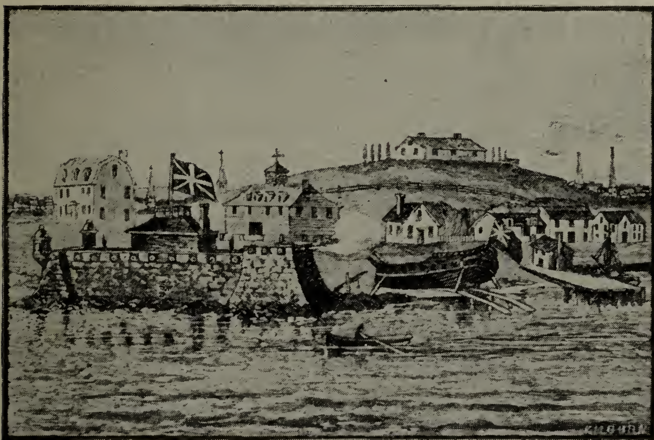
there projected out over the street and blocked the traffic. So far as we know that was the first traffic trouble in Boston.

Man soon began to modify the topography to suit his needs. At the north end of the peninsula, between Copps Hill and the point of land which extended northwards from Beacon Hill, was a cove called Mill Cove. A causeway was built across this cove forming a mill pond. At high tide water was let in from the harbor and at low tide it ran out through the mill, providing power. Later this mill pond was filled in, and the street which was located where the causeway had been, is called Causeway Street.

The cove between Copps Hill and Fort Hill, called Town Cove, was also filled in. The Custom-house Tower is located on made land in this cove. Near the western end of Charlestown Neck was a cove across which a mill dam was built, but later this was also filled in. Tide mills were important in the early days, because there were no steam engines, and there were no waterfalls in Boston from which power could be produced. Therefore the only source of power was from windmills, tide mills and animals.

During the first part of the last century a mill dam was constructed across the Back Bay, and Beacon Street was laid out on it. The mill pond became a nuisance and was filled in about half a century ago making the Back Bay district. A large

part of the South Bay was filled in, and the extensive mud flats on the north side of Dorchester Neck were made into land, upon which much of South Boston is built. Considerable land has also been added to East Boston, Charlestown and Cambridge by filling.



Fort Hill, since Removed, and the South Battery

While man was filling in the bays and making new land, he was also tearing down the hills and using the material from the hills in the filling. The top of Beacon Hill was taken off and Fort Hill was removed entirely. All these changes tend towards a simplification of what was once a very irregular topography. Man has been straightening the shore line and smoothing off the surface of the earth.

Besides filling in bays and tearing down hills,

man also dug canals. One of the most important of these was from the Charles River in Dedham to the Neponset River in Hyde Park. The latter river is there about fifty feet lower than the Charles, and thus water power could be produced along the canal, which is still in existence and is called Mother Brook. As it connects two rivers which flow into the sea on opposite sides of the city, it makes an island of Boston.

One of the latest geographic changes made by man was the building of the Charles River Dam. This turned a tidal estuary into a beautiful fresh water pond, the Charles River Basin, and drowned the offensive mud flats.

Comparison of a modern map of Boston with one made one hundred and fifty years or more ago shows great changes of the shore lines. A hundred years from now the maps of the city will doubtless show many other changes. Man is becoming increasingly important as an agent of geologic and geographic change.

It is unfortunate that so much of the city is built on made land, because it is less solid than most of the natural land and more expensive foundations are necessary. In the Back Bay district there is a layer of artificial fill, beneath which is twenty feet or more of mud and under this a great thickness of clay. The buried gorge of the pre-glacial Merrimac River

lies under the western part of the Back Bay and here the depth to rock is two hundred feet.

For safe foundations solid rock is the best and boulder clay is very good, but clay is much less satisfactory and mud and fill are entirely unsuitable. In the lower parts of Boston the poor foundation conditions render the engineering problems very complex. On the higher lands, as in West Roxbury and parts of Roxbury and Dorchester and other places, rock or boulder clay is near the surface and foundation conditions are excellent. In the lower parts of the city, such as the Back Bay, a deep well commonly shows the following materials in going down from the surface: artificial fill, mud, sand or gravel, clay, boulder clay, then bed rock.

Man settled here because the conditions seemed to suit his immediate needs. As the city grew and man's needs became more complex, he began to change the face of the earth by tearing down hills and filling in bays. This produced more difficulties and problems, but the engineer is constantly attacking and solving them.

THE INFLUENCE OF GEOLOGY ON OUR HISTORY

One event after another through the long geologic ages was preparing the ground for the site of a great city. First the Boston Basin was formed, providing a broad lowland in which a large city might be built. Finally the harbor with its protecting beaches, Winthrop and Nantasket, was completed, and nature had made it possible for man to found an important seaport town.

Had the white man come before the Boston Basin was formed there would have been no reason for him to settle at this particular spot. If the first settlers had arrived before the harbor was made, Boston could not have been a seaport. In many ways geology has influenced the location and development of our city.

When the early explorers sailed along this coast they were attracted by good harbors and here they found one which was surpassed by none for many miles north and south. It was large, with room for five hundred ships, as one of the early writers said, but it was well protected from storms. The numerous peninsulas, or necks, offered easily defended locations for towns, and the islands provided safe pastures.

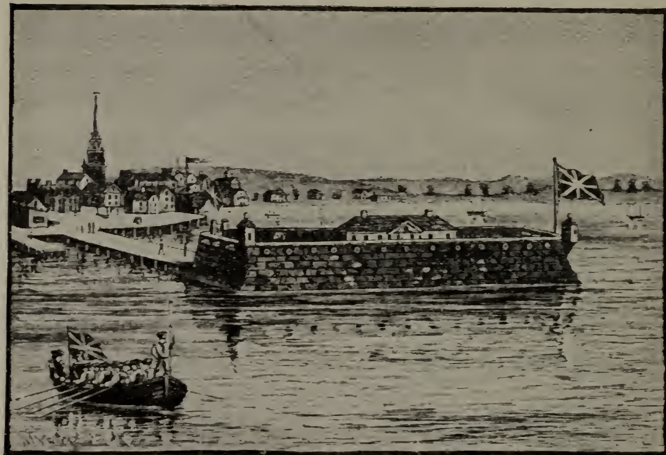
The first settlements were in Weymouth and Quincy, but they did not prosper because the locations were not suitable for trade with the Indians, upon which the early settlers depended. Weymouth was not at the mouth of any river down which the Indians could come in their canoes, and the back country was rugged and pathless. The ship channel to Weymouth was narrow, shallow and crooked, and at an early date Hull became the port of Weymouth.

At Boston the situation was entirely different. The Mystic, Charles and Neponset Rivers provided pathways, down which the Indians came in their canoes to trade furs. The advantages of peninsulas for the first settlements were quickly recognized, and Charlestown Neck, Boston Neck and Dorchester Neck were soon occupied by the colonists.

Boston was preferred to Charlestown for the main settlement on account of the scarcity of good drinking water in the latter place. The large springs in Boston supplied the inhabitants for a time, then wells were dug, and in 1795 water was brought from Jamaica Pond through four wooden pipes made of logs of pitch pine. In 1848 the Cochituate Aqueduct was completed, bringing water from Lake Cochituate in Framingham. Now much of our water comes from the Wachusett Reservoir, over thirty miles away. As the city grows it is necessary to go farther and farther for pure water.

Boston Neck was well situated for defense, either

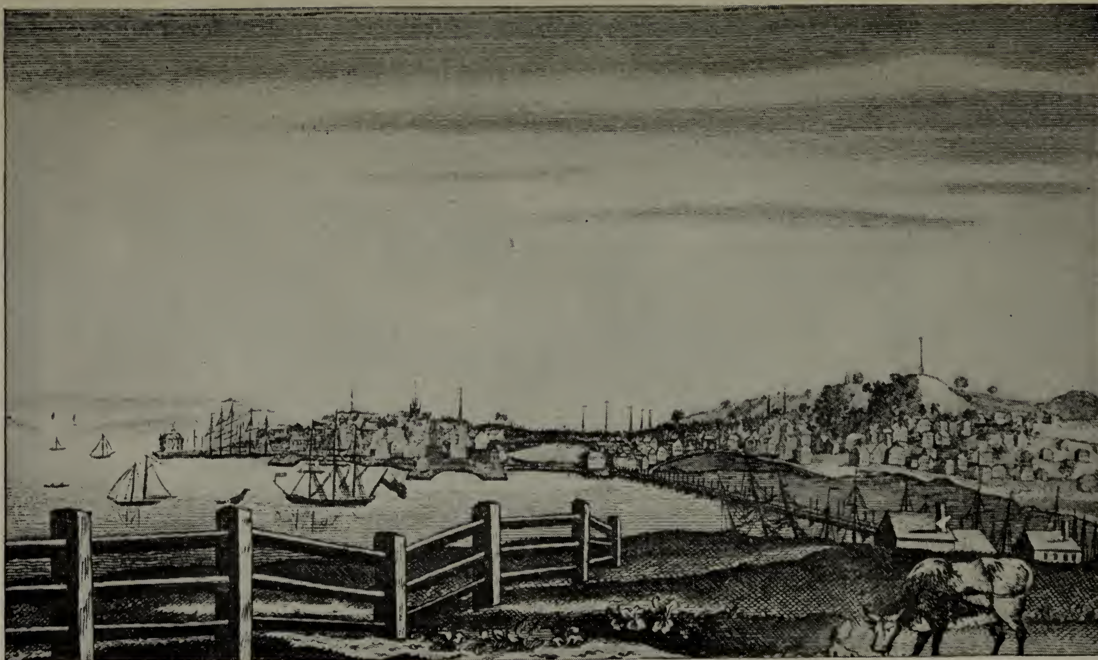
from the Indians or against foreign ships. It was connected with the land by only one narrow neck or isthmus across which fortifications were built. Fort Hill, eighty feet high, offered a good location for a fort which commanded the harbor. This hill was a drumlin, and had it not been for the Ice Age it would



THE NORTH BATTERY AT THE FOOT OF COPPS HILL, ONE OF THE DEFENSES OF THE TOWN

not have existed — indeed, except for the work of the ice sheet there would have been no Boston Neck, for it was largely composed of three hills, all drumlins.

These hills were all of use to the early inhabitants: Fort Hill as the site of a fort, Copps Hill for the location of a windmill and Beacon Hill for a tall beacon, which could be used to alarm the country in time of danger.



View from Copps Hill

Showing Beacon Hill and the Beacon, also Fort Hill which has been removed, and Town Cove which has been filled. The site of the Customhouse Tower is in the center of Town Cove.

During the Revolution the drumlins and other hills of Boston and vicinity figured prominently in history. The hills surrounding the city became of strategic importance in the siege. Most of these were drumlins. The nearest rock hills were in Roxbury and some of these were occupied by Washington's army. Roxbury Heights, a hill of conglomerate one hundred and fifty-five feet high, was fortified but it was not near enough to the city to be effective in driving out the British.

Although the British very carefully fortified Boston Neck, they strangely neglected to occupy the surrounding hills which commanded the town. Bunker Hill in Charlestown, a high drumlin, overlooked the north end of the city. An enemy battery located there would have made it very dangerous for the British in Boston. On the night of the sixteenth of June, 1775, a detachment of Colonial troops built entrenchments on the adjacent Breeds Hill by mistake. When the British saw this the next day they were alarmed and about noon attacked the hill. They were at first repulsed with great losses but finally drove out the Colonial troops when the latter had no more powder. Thus the so-called Battle of Bunker Hill gave the British control of one of the commanding hills, but they still neglected to occupy an even higher hill near the town.

On the night of the fourth of March, 1776, the large drumlin known as Dorchester Heights, which

The Battle of Bunker Hill Seen from the Harbor

has an altitude of one hundred and forty-five feet, was occupied by two thousand of Washington's troops under command of General Thomas. This high hill overlooked the city which was thus at the mercy of the American guns. On the seventeenth of March the British evacuated the city, realizing the hopelessness of further resistance. Again geology played a part since these hills were the work of the great ice sheet.

These few incidents illustrate the ways in which geology affected our early history, and in our later industrial development its influence was quite as important.

In a preceding chapter the large number of waterfalls in New England, the work of the ice sheet, was explained. The streams were displaced from their old channels by the deposits of glacial drift, and wherever the streams cut down upon buried ledges, falls or rapids were formed. These were of great importance in the industrial development of New England. Until after the Revolution the only sources of power were: waterfalls or rapids, tide mills, windmills and animals. Water power from the streams was the most easily available for industry and was soon utilized.

There were no falls or rapids in Old Boston, but at Watertown, Waltham, Newton Lower and Upper Falls on the Charles River, water power was soon developed and used in small mills. Other mills were

started on the Neponset at Milton Lower Mills and elsewhere. The falls on the Merrimac River gave rise to the important manufacturing cities of Manchester, Lowell, Lawrence and Haverhill. The use of the water power of this stream for cotton mills increased until it was said that the Merrimac turned more cotton spindles than any other river in the world.

These power sites were scattered all over New England and caused the development of a large number of manufacturing towns. Most of this development was outside of Boston, or even of Greater Boston, but this city with its excellent harbor became the natural port and trading center of a large industrial area.

Some of the features which made Boston Neck desirable for the location of a small town in the Colonial days became a hindrance as the city grew. The isolation of the peninsula by bays and rivers gave protection when the settlers feared the Indians, but hindered traffic and necessitated long bridges when the city became larger.

The hills which were of use to the early settlers soon became a disadvantage as the population increased. Old Boston on the peninsula had an area of about a square mile, much too small for a large city. It was connected to the mainland by only one road over a narrow neck or isthmus, which made

communication with all the towns except Roxbury, difficult.

These natural defects of the location were a challenge to the ingenuity of the inhabitants, which was recognized and accepted at an early date. The hills occupied much of the scant area and were too steep for convenience, and the shallow bays became a nuisance, but man remedied both of these troubles by moving parts of the hills into the bays. In this ingenious way these hindrances to growth and traffic were overcome and Boston was broadly joined to the mainland. Thus a location suited for a settlement in the wilderness has been adapted by man to the entirely different needs of our modern civilization.

SUMMARY

Our review of the long geological history of the Boston region, from the time, half a billion years ago, when the Braintree Slates were formed, is now ended and we see how the events chronicled in the various chapters of this history affect our daily life.

The oldest rocks of this district, the Braintree Slates, were deposited in a sea in which trilobites and other strange creatures lived.

Later came the intrusion of the diorite, followed by the Quincy Granite.

A very long period of erosion ensued, during which the land was worn down and the deeply buried granites exposed.

Midway between the time when the Braintree Slates were deposited and the present era, this region sank under the sea, and conglomerate, the Roxbury Puddingstone, and slate were deposited. At the same time volcanoes broke out and poured lava into the sea, leaving layers of lava alternating with strata of conglomerate.

Great faults were formed and the area between them sank down, thus making the Boston Basin. The rocks were folded and cracked, and dikes intruded into the cracks.

This was followed by uplift of the land and another long period of erosion, until the main features of the topography were somewhat as they are now, but the Merrimac flowed through Boston and the ocean was far away.

The climate became colder and a great ice sheet formed which covered New England and modified its topography. When the climate became warmer again the ice melted, leaving extensive deposits of gravel, sand and clay.

Then the streams adjusted themselves to the new conditions, often taking very crooked courses.

The land sank again allowing the sea to flow into the valleys, and thus Boston Harbor was formed.

The work of the waves built our beaches and changed the shore.

Finally the white man arrived and began his work of altering the topography to suit his needs.

This summary of the geological story of the region proves conclusively that the country, as we know it, is just one page in the long history of events, that many great changes have occurred in the past and that many more are yet to come. Our everlasting hills are but temporary; they have been formed from mud and sand and eventually they will be washed away as mud and sand.

"There rolls the deep where grew the tree,
O earth what changes hast thou seen!
There where the long street roars, hath been
The stillness of the central sea.

The hills are shadows and they flow
From form to form, and nothing stands;
They melt like mist, the solid lands
Like clouds they shape themselves and go."

Tennyson.

NOTES ON LOCALITIES OF GEOLOGICAL INTEREST IN GREATER BOSTON

NOTES ON LOCALITIES OF GEOLOGICAL INTEREST IN GREATER BOSTON

To become interested in geology and really understand it, one should observe it in the field as well as study it in books. This is not always possible as some localities do not have a variety of geological features. Boston is especially fortunate in this respect, as there is much interesting geology close at hand.

It would be helpful if outcrops of rocks could be found in every school district and near every schoolhouse, but this is not the case and we must make the most of what we have. An attempt has been made to list some of the localities where features of geological interest can be found. Even if there is nothing more exciting than a drumlin within a reasonable distance from the school, that is worth knowing about. From many of the drumlins views may be obtained over the city or harbor, and other points of geological interest seen.

In many cases a single ledge of conglomerate, or slate, or felsite may be the only matter for geological study near a school, but this will repay a visit. One can thus become familiar with the kind of rock in his neighborhood, and by comparing it with the

description of other rocks, be better prepared to recognize them when they are seen.

Outcrops which are now accessible may become covered with buildings, and new excavations may expose interesting features now hidden. Therefore no list of the geological localities can be final, but such a list may serve as a guide for further investigation.

Old Boston. The old part of the city is underlain by slate which is buried under a mantle of clay and boulder clay, therefore the visible geology is restricted to the drumlins, which are three in number, and chance excavations in the clay. Beacon Hill, the largest drumlin, now reaches a height of 105 feet and was formerly 75 feet higher. Copps Hill is much smaller but has the typical drumlin form. The third drumlin, Fort Hill, has been almost completely removed, and a slight elevation at Fort Hill Square is all that is left of it.

The fact that the Back Bay and the area about the North Station, as well as other parts of the city proper, are on made land is interesting. From time to time excavations are made which show the boulder clay of a drumlin or expose a good section of the blue clay. Sometimes stratification can be seen in the clay or sand, and occasionally the yellow clay on top of the blue clay can be seen.

East Boston. Here the depth to rock is great, and the underlying slate is nowhere visible save in deep excavations. There are, however, several large

drumlins. The largest, highest and most perfect is Orient Heights which has an altitude of 160 feet. It was separated from the mainland and from the larger part of East Boston by tidal creeks and was called Breeds Island. Due to extensive filling the island character is being lost. The Blackington School is on the side of this drumlin. Byron Street passes over a drumlin 60 feet high, and the John Cheverus School is at the foot of it. Eagle Street is on a large drumlin, Eagle Hill, on top of which is a reservoir. The summit of this hill is over 80 feet above the harbor, and the Chapman School and several others are on its slopes. There are two small drumlins in Wood Island Park, and from here some of the drumlin islands in the harbor can be seen. One may also get some idea of the extensive filling by which so much land has been made. Webster Street extends over the summit of another drumlin which is more than 60 feet high. The Samuel Adams, Commodore Barry and Plummer Schools are located on it.

Charlestown. This section of the city is similar to East Boston in having large drumlins and no ledges although it is underlain by slate. The two large drumlins of Bunker and Breeds Hills have played an important part in the history of the city. The first is about 105 feet high and the second 80 feet. On the second is the Charlestown High School facing Bunker Hill Monument. From this the varied

topography of Greater Boston can be seen, and a good idea of the Boston Basin obtained. The high land to the north and the hills in the Basin show up well on a clear day. The numerous islands of the harbor may also be seen.

South Boston. This is another district almost devoid of objects for geological study, with the exception of the drumlins and the views of the harbor islands. It is underlain by slate which has been exposed in several excavations. South Boston is built on three drumlins. The smallest of these is in the western part of the district, and the Lawrence School at Third and B Streets is on its summit at an elevation of 30 feet. Telegraph Hill, or Dorchester Heights, as it was formerly called, is the highest land in South Boston and is a very large drumlin. Its commanding position made it of military importance during the Revolution. The summit has been partly removed to make room for the South Boston High School, but the elevation of the highest part is still 145 feet. There is a view of the harbor from the hilltop and a better one from the top of the monument. The Shurtleff and Thomas N. Hart Schools are on the slopes of this drumlin. The third drumlin has its center at Broadway and M Streets, at an altitude of 70 feet. Castle Island is another drumlin, now attached to the land by filling. From this island an excellent view of the harbor and its drumlin islands may be obtained. Nearly all the land north

of First Street was made by filling. Rock is known to be not far below the surface at a number of places and in excavating for the dry dock, slate was found.

The Back Bay and the South End. These two districts are almost entirely made land. Although there are no geological features of interest here, most of the schools are reasonably near the Beacon Hill drumlin or the hills of Roxbury, where there is much to see. It is interesting to know that along Washington Street was a narrow strip of natural land with shallow bays and mud flats on either side.

Roxbury. The visible rock here is all conglomerate except for trap dikes, though the northern end of Roxbury is underlain by slate. The broad Shawmut Anticline, so named by Professor Crosby, extends through Roxbury, northern Dorchester and West Roxbury. Here the conglomerate was raised up and has been exposed by erosion.

Ledges are numerous in Roxbury in strong contrast to the neighboring districts of made land. Franklin Park offers many opportunities to see the conglomerate, and in the old quarry near Schoolmaster Hill are trap dikes. Large glacial boulders are numerous; there is a very prominent one on the brow of the hill near the Toboggan Chutes. Many of the ledges show smooth joint surfaces. At the edge of the Park, on Walnut Avenue opposite the end of School Street and near the George Putnam

and Theodore Roosevelt Schools, is a ledge of conglomerate which has been smoothed off by the ice sheet. So numerous are the points of geological interest in the Park that it is not practical to list and locate all of them.

There are extensive conglomerate ledges on the hill behind the Henry L. Higginson School at Walnut Avenue and Harrishoff Street. Fountain Square at Walnut Avenue and Townsend Street shows ledges of the same rock with small pebbles, and there are several steep joint faces and conglomerate boulders. In Washington Park, behind the Lewis School at Walnut Avenue and Bainbridge Street, are smooth glaciated ledges of conglomerate with sandy layers, and in the Marcella Street Playground it is again found with sandy layers, also a foreign boulder of a different rock, which was brought from a distance and dropped by the ice. Nearby in Highland Park are ledges of conglomerate with sandy layers, and a good view may be obtained. Here fortifications were erected in June, 1775. On Highland Street just west of Cedar Street are more conglomerate ledges.

Parker Hill is a large drumlin on top of a rock hill, and on the north side great ledges of conglomerate extend far up the slope. The Comins School is near these ledges and on the other side of Parker Hill, along Heath Street near the Jefferson School, are more exposures of this rock. It is also found at Winthrop and Fairland Streets, and on Buena Vista

Street are ledges of fine conglomerate with sandy layers. In the yard of the Memorial High School at Warren and Townsend Streets are ledges and boulders of conglomerate, while the William Lloyd Garrison School is not far from those of Franklin Park. This school is located on a drumlin near Elm Hill Avenue and Hutchins Street. Many other outcrops of this familiar rock are scattered about Roxbury.

Dorchester. The geology here is not as simple as in Roxbury. In the northern part the rock is conglomerate with occasional trap dikes. This is the large Shawmut anticline which extends eastward into Dorchester. South of Franklin Field and Fields Corner is a belt of slate about a mile wide. Here we have a syncline where the conglomerate has been folded far below the surface. South of this slate is a broad belt of conglomerate extending into Milton, which contains areas of felsite and melaphyre and constitutes the Mattapan anticline. While this is more than a mile wide, it is not as extensive as the great anticline in Roxbury and northern Dorchester.

The northern conglomerate can be seen at many places, some of which are the following: At the end of Woodcliff Street off Howard Street are broad ledges of it showing joint faces. The Phillips Brooks School is not far away. At Quincy and Barry Streets are ledges, and at Adams and East Streets on Meetinghouse Hill, near the Mather School, are ledges of fine conglomerate. Nearby on Percival Street are

more ledges, and at the end of the street is Ronan Park on Mount Ida, a drumlin. On Savin Hill near the John Lothrop Motley School are extensive ledges of conglomerate, mostly fine with sandy layers. The numerous smooth, steep surfaces of the rock are joint faces formed where it has broken along a joint. From the summit of the hill a view of the harbor and its drumlin islands may be obtained. On Geneva Avenue, opposite Everton Street, are extensive conglomerate ledges showing glaciated surfaces and joints.

The slate may be seen at Wildwood and Harvest Streets where there is a large ledge with the strata nearly vertical. The conglomerate of the Mattapan anticline may be seen in the eastern part of Cedar Grove Cemetery where it is fine grained, dips to the southeast, and shows glacial smoothing and scratches. In Dorchester Park, along the river at Dorchester Lower Mills, at River and Monponset Streets and at other places the conglomerate shows up well. On the east side of Harvard Street, near the south boundary of the new Calvary Cemetery, are ledges showing nearly vertical layers of conglomerate, sandstone and slate.

At West Seldon and Crossman Streets is a quarry of pink felsite, and nearby, at Babson Street and Cook Terrace, close to the Edmund P. Tileston School, are felsite ledges. There are others along and just west of the railroad between Blue Hill Avenue

and Oakland Street. Ledges of melaphyre may be seen along Morton Street near Codman Street. Drumlins are numerous in Dorchester. Mount Ida has already been mentioned, Jones Hill, near Uphams Corner and near the Edward Everett School, is another, and Mount Bowdoin, near which are the Oliver Wendell Holmes School and the John Marshall School, is a large drumlin, while at Blue Hill Avenue and McClellan Street is still another, with the Robert Treat Paine School nearby. In the southern part of Dorchester is a large drumlin over which Standard Street passes. This has a great conglomerate boulder on its summit. Wellington Hill, near Blue Hill Avenue and Morton Street, is a typical drumlin.

Jamaica Plain. The large Shawmut anticline extends through this district and the rock is all conglomerate with the exception of trap dikes, but there is other interesting geology. Conglomerate ledges abound in Franklin Park, as has been mentioned already, and in the old quarry are trap dikes. The Bowditch School on Green Street is near many conglomerate ledges, which may be seen at Parley Vale, Rockview Street and elsewhere. Between Boylston and Paul Gore Streets are extensive outcrops of this same rock, and Sheridan Avenue passes over a small drumlin on top of a rock hill. On Wachusett Street opposite the Francis Parkman School is a trap dike in a conglomerate ledge, which shows smooth joint

faces. Numerous ledges of this rock may be seen in Forest Hills Cemetery.

The Arnold Arboretum offers many interesting features. Bussey Hill is a drumlin, and on Hemlock Hill the conglomerate ledges show well. Peters Hill at the southwest end of the Arboretum is a large drumlin and is near the Longfellow School in Roslindale. Along Centre Street, opposite the Arboretum, is a large quarry in conglomerate with trap dikes.

The Agassiz School on Burroughs Street is on a sand plain, and Jamaica Pond occupies a large kettle hole in this sand plain. There is a very perfect kettle hole directly in front of the Children's Museum and another nearby. The Jamaica Plain High School is on the side of a small drumlin. Moss Hill is a large drumlin and the hill on the west side of Jamaica Pond is another.

West Roxbury. The geology of this district is rather complicated. The northern part is underlain by the conglomerate of the Shawmut anticline, south of which is a belt of slate that is the western extension of the Dorchester syncline. There is a small area south of this on the Mattapan anticline where the rocks are conglomerate and felsite. Bellevue Hill and the area west of it are underlain by granite. These last two rocks are part of the floor of the Boston Basin, which shows because the overlying conglomerate and slate have been worn away.

Drumlins are numerous in West Roxbury. Brown Avenue and Sherwood Street in Roslindale pass over a drumlin. Mount Vernon Street is on a large drumlin, at the foot of which is the Robert Gould Shaw School, and Bellevue Hill, a drumlin, is the highest land in the city of Boston. Mount Benedict Cemetery is on a drumlin, and Captain John or Monterey Hill, near Poplar Street on the border of Hyde Park, is another.

The interesting features of the Arboretum and the large quarry on Centre Street have already been mentioned in the section on Jamaica Plain. On Washington Street, between La Grange and Grove Streets, is a quarry showing a large trap dike cutting through the granite. Along Grove Street, north of Washington Street, are felsite ledges, and these are part of the neck of an old volcano. They represent lava which hardened in the throat of the volcano. At Grove and Centre Streets is a large quarry in granite, showing a broad trap dike and several smaller dikes cutting across it. Along the banks of the Charles River, a little north of Spring Street, is an esker and a good-sized sand plain in which is an extensive sand pit. These are near the pumping station of the Brookline Water Works.

Hyde Park. This is another district with complex geology, and conglomerate, felsite and granite are all found here. There is a large ledge of conglomerate at West and Austin Streets. Felsite ledges are

common; there is one at the end of Gordon Avenue, not far from the Henry Grew School, and on Riverside Square near Metropolitan Avenue are ledges of red felsite. Bald Knob in the Stony Brook Reservation is composed of felsite and is the neck of another ancient volcano. There are also other felsite ledges scattered throughout the Reservation. Brush Hill on the border of Milton is a large drumlin, as is Captain John Hill, already noted. An interesting feature, partly of human origin, is Mother Brook which connects the Charles and Neponset Rivers and makes an island of Boston. It was dug to produce power, and there are mills along its course.

Brighton. The broad syncline of slate which underlies Cambridge and Somerville extends westward across the northern part of Brighton. South of that is the northern anticline of conglomerate in which are lava-flows, the rock being known as melaphyre. This anticline is not as broad as the large one in Roxbury, and it has been overturned and much broken by faulting. South of this, extending through the Chestnut Hill Reservoir, is a belt of slate. In the Allston Playground, near the corner of Warren Street and Commonwealth Avenue and not far from the Andrew Jackson and Frederick A. Whitney Schools, are extensive ledges of melaphyre with amygdules of quartz and epidote. These amygdules were formed by minerals crystallizing in bubbles in the lava and filling them. Strata of slate and sand-

stone may also be seen, and in the western part of the playground are later trap dikes cutting the melaphyre, which in turn cuts the slate. There are extensive melaphyre ledges back of the Brighton High School. On the north side of Washington Street, opposite the end of Lake Street, is a large quarry in melaphyre with sandstone and conglomerate on the south side, also a trap dike cutting the other rocks. Along the north side of Chestnut Hill Reservoir are ledges of conglomerate and slate dipping steeply to the north, and along Commonwealth Avenue southwest of Washington Street are ledges of conglomerate with trap dikes. There are also numerous outcrops of this rock along the east side of Chestnut Hill Avenue between South and Union Streets with exposures of melaphyre on the west side.

An excellent example of glacial polish may be seen in the conglomerate ledges on the east side of Foster Street, about a quarter of a mile north of Commonwealth Avenue. On Lake Street in the grounds of Saint John's Boston Ecclesiastical Seminary is a smooth glaciated ledge of sandy conglomerate. In the west end of Brighton are several drumlins including Nonantum and Bigelow Hills.

Newton. The formations of Brighton extend westerly across Newton. The northern slate underlies the northern part of the city, the northern anticline of conglomerate goes through its center, and in the middle of this is a broad area of melaphyre. The

large Shawmut anticline extends west through Newton Center and is composed of conglomerate with a large area of melaphyre included. That part of Newton north of the main line of the Boston and Albany Railroad is a great sand plain.

On Walnut Street at the end of Dunklee Street, there are ledges of conglomerate to the east with felsite on the west side, probably separated by a fault. There is a quarry in melaphyre on the south side of Florence Street near Boylston Street and ledges of conglomerate on Langley Road north of Boylston Street. Along Beacon Street between Centre and Hammond Streets are high ledges of this same rock with interbedded slate and prominent joint faces. The characteristics of the conglomerate may be seen to good advantage here. This rock occurs also on Hammond Street between Beacon Street and Commonwealth Avenue. On Gardner and Jewett Streets are ledges of slate cut in all directions by trap dikes, showing much disturbance. There are cliffs of melaphyre west of Lowell Street between Commonwealth Avenue and Highland Street.

Of the many drumlins in Newton, Oak Hill and Bald Pate Hill are in the southern part, Mount Ida is near Newton Corner and Waban Hill is just northwest of the Chestnut Hill Reservoir. There are ledges of conglomerate at Echo Bridge in Newton Upper Falls, and nearby, on the north side of Eliot Street almost opposite Hale Street, are potholes

made by a stream flowing under the ice sheet. About half a mile southwest of Riverside the railroad cuts through a large esker, which connects with an extensive sand plain containing kettle holes. Near Norumbega Park is an esker projecting into the river.

Brookline. The northern anticline of conglomerate crosses the north corner of this town, and south of that a narrow belt of slate extends eastward from Chestnut Hill Reservoir through the northern part of the town. The great Shawmut anticline covers the west end, and in the southwest corner is an area of melaphyre. Along Hammond Street north of Newton Street are ledges of melaphyre, and near Boylston Street are ledges of conglomerate. Ledges of conglomerate with trap dikes extend along Newton Street between South and Grove Streets, and the same are found in the grounds of the Brookline Country Club, also ledges of the conglomerate on Warren Street near Walnut Street. Drumlins are important features here. Prominent among these and well known is Corey Hill, 260 feet high, a large drumlin, which commands a beautiful view across the city. Other large drumlins are Fisher Hill, Singletree Hill, Walnut Hill and Aspinwall Hill.

Quincy. Here again the geology is quite complex. In the northern part is a belt of conglomerate, the eastern extension of the Mattapan anticline with a narrow belt of slate in Squantum. South of the conglomerate is a broad belt of slate, the eastern end

of the Milton syncline, and then again a narrow belt of conglomerate. Still farther south and extending into North Weymouth is the Braintree Slate, much older, of Cambrian Age. In the Blue Hills and extending easterly from them are granites and similar rocks.

At the granite quarries on North Common Hill and in West Quincy are many points of geological interest. On this hill the horizontal jointing shows well, and in one of the quarries a large inclusion of slate occurs, while on the north side of the hill the complex relations of the granite and slate may be studied to good advantage. The West Quincy quarries are interesting on account of their great depth. South of the large quarries is the old Bunker Hill Quarry. At Rock Island on Houghs Neck, ledges of conglomerate and melaphyre deserve notice. Between the deposition of two layers of conglomerate a lava-flow was poured out over the rock. The northern bed of conglomerate is the oldest. The conglomerate at Squantum Head is unusually interesting on account of the peculiar characteristics of the rock. It is called tillite and is believed to have been formed in a very old glacial period millions of years before the last Ice Age. Tillite is a conglomerate made from boulder clay instead of from water laid gravel. On the north shore back from the point is a finely laminated green slate and on the south shore a banded reddish slate.

There are several large drumlins in Quincy among which are Forbes Hill, Presidents Hill, Quincy Great Hill and the hill with the water tower at Squantum. From Houghs Neck, Weymouth Great Hill, a beautifully symmetrical drumlin, shows up well and the drumlin islands in the harbor, some partly cut away by the waves, are visible.

Milton. There are several kinds of rocks in this town. Along the Neponset River is conglomerate of the Mattapan anticline. There are two areas of felsite and melaphyre in the southern part of this anticline, which represent a subsidiary arch where the floor of the Basin has been bent up and exposed by erosion. The areas of felsite in Milton are thus another arch, the fourth or Milton anticline.

South of this anticline is a belt of slate, the Milton syncline. Continuing southward there is a long band of conglomerate along the southern border of the Boston Basin and beyond this the granitic rocks of the Blue Hills. Besides the granite there is a large area of quartz porphyry in the hills.

Along the Neponset River just below Milton Lower Mills are ledges of conglomerate and slate, and there is a small anticline in the slate on the south side of the railroad between Milton Station and Central Avenue. Numerous exposures of felsite and melaphyre may be seen about half a mile south of Mattapan, between Blue Hill Avenue and the Blue

Hill Parkway, and also between Mattapan and Central Avenue.

Milton Hill and Brush Hill are large drumlins. Along Brush Hill Road between Mattapan and Brush Hill is a very handsome stone wall containing many red felsite boulders. Hillside Pond between Border Road and Hillside Street in the Blue Hills is in a kettle hole.

The geological features of the Blue Hills are too numerous to describe here, but two of them deserve especial mention. On the south side of the Blue Hill River Road, a short distance west of Randolph Avenue and on the bank of the stream, are several potholes. Just west of these on the north side of the road are ledges of giant conglomerate containing very large pebbles or boulders.

Dedham. Granite, diorite and felsite predominate here and many outcrops of these rocks may be found. Most of the area east of Washington Street is covered by an undulating sand plain with many kettle holes and eskers. Attention may be called to the very circuitous course of the Charles River, caused by its displacement from its original channel by the ice sheet. On East Street a little west of Canton Street, and just over the line in Westwood, is the northern end of a large esker which extends southward across Everett Street into Norwood.

Needham. Melaphyre in the west, felsite in the center and granite in the eastern part are the prin-

cipal rocks of Needham. The granite and felsite, the older rocks, form a tongue projecting into the Basin, and the melaphyre is in the western extension of the Basin. High Rock is a knob of felsite.

There is a sand plain with kettle holes east of Chestnut Street, and Birds Hill is a drumlin. Just north of Great Plains Avenue and a little east of Greendale Avenue is an esker. Between Highland Avenue and the railroad and within half a mile of the river is a network of winding eskers and kettle holes.

Wellesley. The southwest extension of the Boston Basin crosses the southeastern side of the town, and the northern and western parts are on the granite rocks outside the Basin. The Basin rocks consist of melaphyre, conglomerate and slate. Melaphyre outcrops in the eastern part of the town and at Wellesley Hills where it is cut by large dikes.

Sand plains cover much of the town and there are numerous kettle holes. These may be seen on the Wellesley College campus. Waban Lake and Morses Pond are kettle ponds. Several large drumlins rise above the sand plains. Maugus Hill with an altitude of 320 feet is the highest of these and just northeast of it are two other drumlins. The Babson Institute is on a drumlin; there is one at the eastern end of the Wellesley College grounds and two others between this and the Institute.

Weston. The border of the Boston Basin is at

the eastern edge of the town close to the Charles River. West of the border the rocks are principally granite and diorite.

On the north side of the railroad, just west of Roberts Station, are ledges of diorite cut by granite with diabase dikes cutting both. West of the station and on the south side of the railroad is a knoll showing diorite cut by granite which is cut by diorite (trap) dikes, which in turn are cut by diabase (trap) dikes. Continuing northward one may see two potholes in a ledge between the railroad and the reservoir, and near the Stony Brook Station is quartzite cut by diabase dikes. There are more ledges of diorite cut by granite on the south side of the railroad just west of Stony Brook Station. Doublet Hill is composed of diorite cut by granite. An esker may be seen southwest of the railroad and brook opposite Kendall Green Station, and there is another which extends into the Charles River north of the mouth of Stony Brook and not far from Roberts Station. Near Norumbega Tower is still another esker.

Waltham. The southern part of the city is in the Boston Basin and is underlain by slate, and in the northern part the land is higher and the rock is diorite cut by granite. In the southwestern corner of Waltham there is an area of granite. Prospect Hill is composed of diorite cut by granite, and it stands on the edge of the Boston Basin. From the summit a good view may be had of the Basin dotted

with its many drumlins. The Blue Hills which form the other wall of the Basin are plainly visible. Prospect Hill has the roche moutonnée form. Bear Hill is another knob of diorite cut by granite. Owl or Helmet Hill in the east part of the city is a drumlin. There are eskers close to the Weston line.

WATERTOWN. The rock here is slate, as Watertown is entirely in the Boston Basin. It is exposed in an old quarry at Templeton Parkway and Edgecliff Road and shear zones may be seen. Common Street passes over Meetinghouse Hill, a large compound drumlin from which a good view may be obtained, and there is another compound drumlin at the west end of the town north of Main Street. Palfrey Street extends over Whites Hill, another large drumlin.

BELMONT. The southeastern part of the town is in the Boston Basin and is underlain by slate, and the northwestern part is on the highlands where the rock is diorite cut by granite. Pleasant Street extends along the foot of the hills which form the northern border of the Boston Basin, and here one may see the character of its northern wall. This street is approximately on the line of the northern boundary fault. Just west of Belmont Station, Concord Avenue rises steeply where it climbs out of the Basin.

Along Pleasant Street 350 feet east of Trapelo Road are ledges of diorite which continue to Charles

Street, and at the corner of Clifton and Prospect Streets exposures of diorite cut by granite are seen. The moraine mentioned under Arlington continues into Belmont. At the corner of Waverly Oaks Road and Trapelo Road is an esker.

Arlington. This is another town partly in the Boston Basin and partly on the highlands north of it. The southeastern and lower end is underlain by slate which is not exposed. Extending up the slope from Pleasant Street is a belt of granite, and the western end of the town is largely on diorite. Pleasant Street is at the foot of the northern wall of the Boston Basin along the boundary fault. Spy Pond and the Mystic Lakes are kettle ponds in the buried valley of the old Merrimac. From the summit of Arlington Heights an excellent view may be obtained across the Basin. The rocks of Menotomy Park are diorite and pegmatite, which is similar to granite but has large crystals and therefore is often called giant granite.

On Arlington Heights at the northeast side of the water tower are ledges of syenite, a rock similar to granite but without quartz, and a trap dike.

Along Summer Street between Mill and Brattle Streets are numerous outcrops of diorite cut by dikes of granite and pegmatite. Just south of the corner of Bow and Summer Streets are ledges of quartzite of Pre-Cambrian Age, and 800 feet east of this place along Summer Street is quartzite cut by granite and

diorite. A moraine composed largely of boulders extends from the corner of Eastern and Highland Avenues toward Lincoln and Park Avenues.

On the north side of the Arlington Reservoir is an esker which extends into Lexington. On Grove Street south of the railroad is an excavation in the remnant of an esker showing well its stratification and composition.

Cambridge. The city is underlain by slate but this is covered nearly everywhere with a considerable thickness of clay, sand or boulder clay. The buried valley of the pre-glacial Merrimac lies under the western part of the city, and Fresh Pond is in a large kettle hole in this valley. There are several drumlins, none of which are very prominent. Harvard College is on a low drumlin and there is a higher one in East Cambridge. The large pit north of Concord Avenue near the railroad has interesting features. The Harvard Observatory is on a ridge known to geologists as the Fresh Pond Moraine. This was made by a readvance of the ice over the sand plain. The Agassiz Museum on Oxford Street should be visited. It holds much of geological interest, especially the large model of the Boston Basin, which enables one to visualize the relations of the lowland with its scattered drumlins and the surrounding highlands.

Somerville. This might well be called the city of drumlins, for there are eight drumlins within its

limits. The largest and highest is College Hill with a length of 4,300 feet and an altitude above sea level of 140 feet. The long axis of a drumlin marks the direction of ice movement at the time the drumlin was formed, and the direction of the axes of the drumlins of Somerville shows that the ice was moving southeast. The next largest drumlin in Somerville is Winter Hill, which has a length of 4,000 feet and an altitude of 135 feet. The other drumlins are Winthrop, Spring, Central, Prospect and Cobble Hills, also Mount Benedict. In some of these the ledge rises to a considerable height, and at the large quarry on Mystic Avenue near Temple Street, rock may be seen rising high up in Winter Hill.

Somerville is underlain by slate in which are many trap dikes. These may be seen at the old Almshouse Quarry, Clarendon Avenue and Weston Avenue, and near the Junior High School at Clarendon Hill, also in the ledges back of the firehouse at the corner of Lowell Street and Somerville Avenue, and at the end of Warwick Street near the railroad. In the big quarry on the north side of Winter Hill there are folds in the slate and it is cut by trap dikes. A sheet of trap with calcite veins may also be seen. In the old quarry at the corner of Holland and Cameron Streets by the Zebedee E. Cliff School are ledges of slate cut by dikes which contain quartz and calcite veins.

The Medford diabase, a coarse trap, may be seen

at Powder House Square and on Granite Street, where it has been mistaken for granite.

MEDFORD. The southern part of the city is in the Boston Basin and is underlain by slate in which there are many trap dikes. Near the border of the Basin is an area of felsite, and the northwestern part of the city is on granite and diorite. In the extreme northwestern corner, in the Middlesex Fells, is a belt of quartzite, of Pre-Cambrian Age. The western part of the Fells is largely quartzite, granite and diorite and the eastern part felsite.

Along Governors Avenue is a large trap dike which extends northerly into the Fells. The dike cuts the slate, granite and felsite and is thus younger than any of these rocks. This trap is coarse and is known as the Medford diabase. It has disintegrated to a considerable depth leaving boulders in the soil. These are not glacial boulders but are what is left after the surrounding rock has decayed. The quarry on the Fellsway at Paris Street shows felsite porphyry cut by a trap dike with veins of specular hematite and calcite. Porphyry is the name of a rock in which one mineral has formed large crystals and the others have made a fine ground mass. Just west of College and Frederick Streets and back of the Lorin E. Dame School are exposures of the Medford diabase. At Winthrop and Wyman Streets are outcrops of conglomerate with the pebbles much sheared and squeezed.

Near Riverside Avenue and the Fellsway there are pine stumps in the marsh, showing where salt water has encroached upon former forest land. Nearby, across Riverside Avenue, is a large clay pit in which the stratification of the clay may be studied.

MALDEN. This city is partly in the Boston Basin but the northern edge is on the highlands, and from some of the high points in the southern part of the Middlesex Fells views may be had across the Basin. Slate underlies the southern part of Malden and there are felsite and granite in the northern part. The boundary of the Boston Basin extends across the city, and there is here as elsewhere a strong contrast in the topography north and south of the boundary.

Along the Fellsway East by the reservoir are ledges of a rather dark felsite porphyry cut by a trap dike. At Fellsway East and Glenwood Street is a large quarry in the felsite porphyry which is there rather granitic. At Glenwood and Grace Streets by the Glenwood School is more of the same porphyry. Granite may be seen at Rand and Prosper Streets and at Sylvan Street near Gibson Street. In Maplewood at Jacob and Granite Streets is a quarry in dark felsite porphyry.

EVERETT. Slate underlies Everett but is generally deeply buried. The city is entirely within the Boston Basin. On Luke Street, just north of Chelsea Street, is a sheet of trap dipping to the south. The

slate beneath it can not now be seen. Nearby at Evelyn Road and Malden Street is a small outcrop of quartzite which was a layer of sandstone in the slate.

There are several drumlins in the city. Mount Washington in the northeastern part is a large one, and the oil and gas works in South Everett are on a small drumlin.

CHELSEA. Slate also underlies this city but generally at a considerable depth, and the large drumlins furnish most of the material available for geological study. The Naval Hospital is on a drumlin, and Powder Horn Hill, on which is the Soldier's Home, is an excellent example of a very large drumlin. It rises 200 feet above the sea and from its summit the numerous drumlins of the vicinity show to good advantage. At the foot of the hill on the northeast side is a large clay pit where one may study the characteristics of the clay.

REVERE. Rock is here deeply buried and the city is built on clay except where there are drumlins. A very large one may be seen north of the Revere Beach Parkway, opposite Powder Horn Hill, and Beachmont is a typical drumlin with the eastern end cut into by the sea. There is a very large clay pit at the eastern end of Mountain Avenue, the clay from which is used for making hollow tiles for fireproof construction.

Revere Beach is a good example of a barrier

beach. The bay which formerly existed between it and the mainland has been largely filled in by deposition, and part of it is now dry land and part salt marsh in which are the stumps of trees.

WINTHROP. There is no rock known near the surface in this town, and it is built upon clay and drumlins. Grover's Cliff and Great Head are both drumlins with the eastern ends cut away by the waves, and the central part of the town is on a drumlin. Winthrop Beach is a barrier beach built by the waves. During a storm the ceaseless grinding of the pebbles on this beach may be heard. In this process of grinding they are finally reduced to sand. Shirley Gut is kept open by the tidal scour, and at half tide the swift tidal currents are interesting.

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INDEX

INDEX

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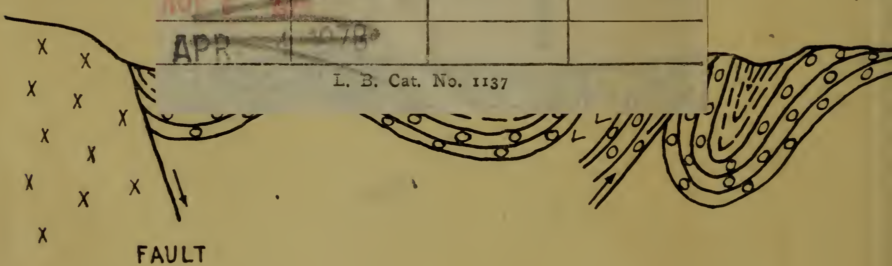

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